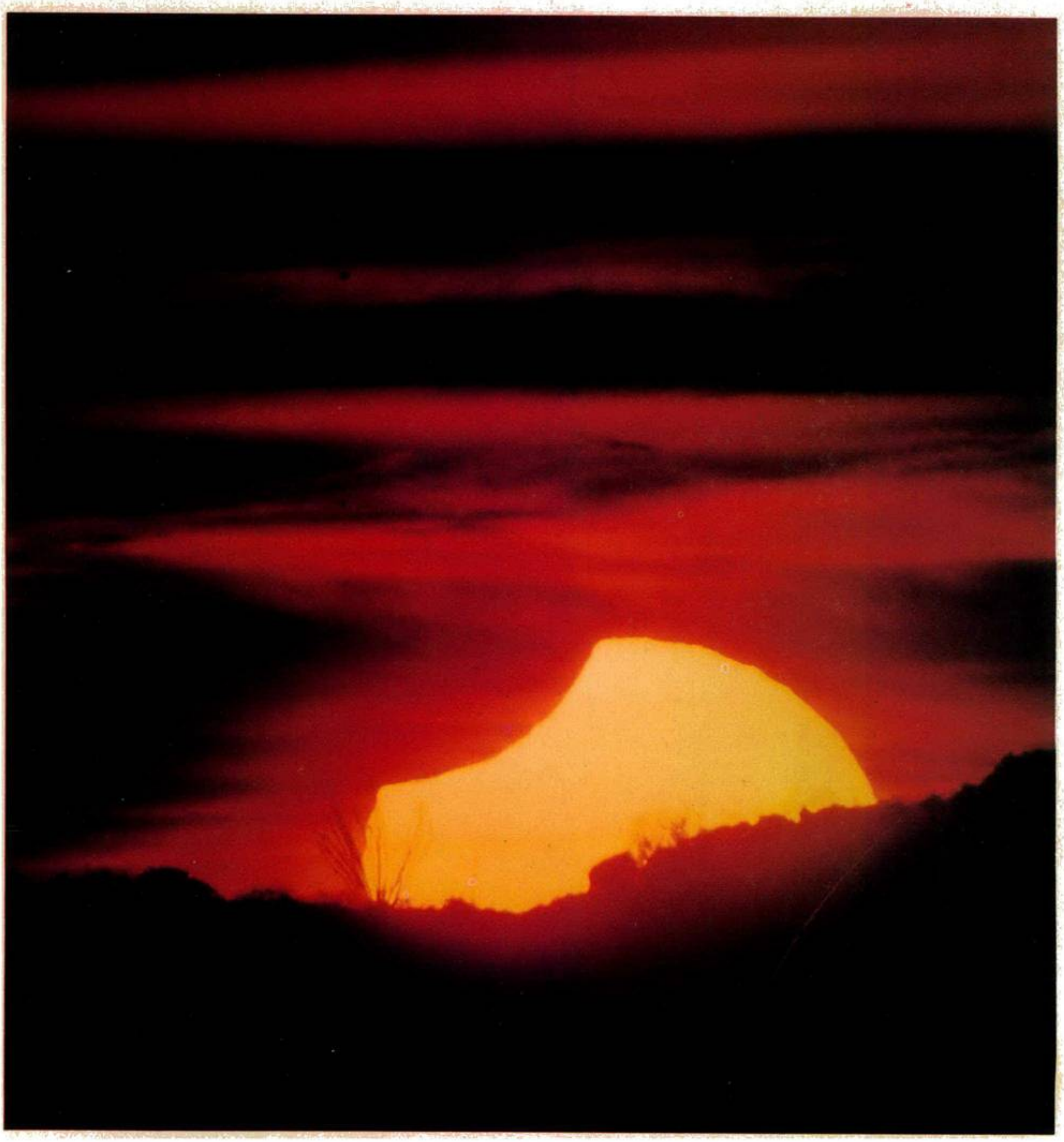
ASTRONOMY

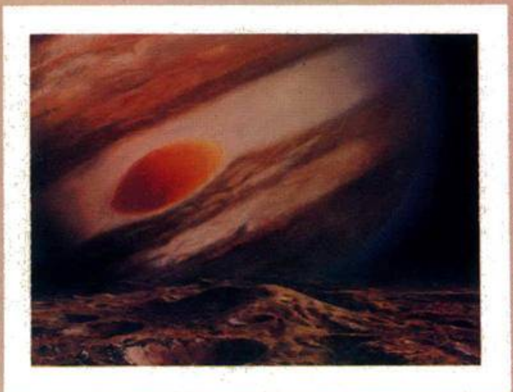
JUNE 1977 $1.50



NEW FROM

To you, our readers, ASTRONOMY now offers a series of 8 dynamic, new, full color Art Reprints of some of the best paintings — by artists John Clark, Victor Costanzo, James Hervat, Mark Paternostro, Adolf Schaller and Rick Sternbach — that have appeared in ASTRONOMY Magazine.

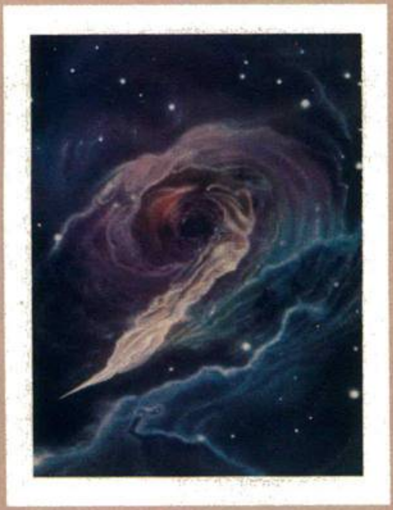
Adding to the drama, depth and realism of each piece, these Art Reprints are printed on 80 lb. linen finish paper, and are coated with a high gloss varnish. And each reprint is surrounded with a 3/4 inch white border,



Actual Size: 17" x 22"

Jupiter From Io

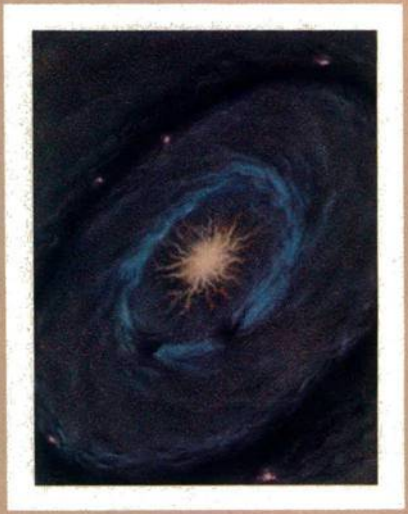
This dramatic painting reveals an incredible vista that man may never witness first hand: the incredible bulk of Jupiter looming over the surface of its satellite Io. Located deep within Jupiter's intense magnetic field, Io is one of the most lethal places in the entire solar system. To view this scene, we must rely on the imagination of artist John Clark.



Actual Size: 17" x 22"

Black Hole

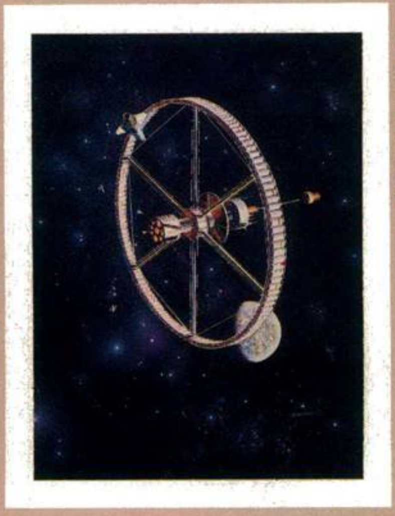
A nearly invisible small black hole speeds through a dense interstellar cloud of gas and dust, leaving behind a trail of gravitationally disturbed material. The infalling material becomes hot and emits light as it drains out of the known universe. Artist Mark Paternostro speculates on the appearance of these still undetected objects.



Actual Size: 17" x 22"

The Galactic Core

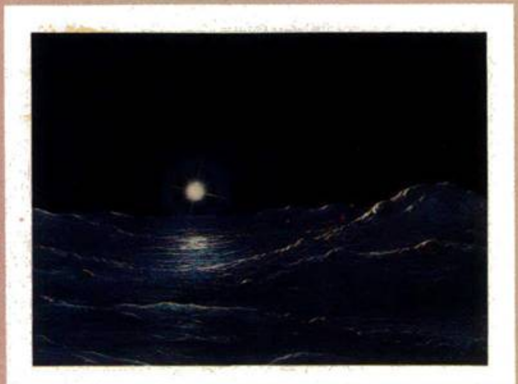
The nucleus of our galaxy is one of the true unknowns in our universe. Recent radio and infrared observations suggest that two titanic swirling rings of gas and dust occupy the core of our galaxy. These rings were apparently produced by an explosion 10 million years ago. Victor Costanzo's painting indicates that actual conditions at the galaxy's center remain a mystery.



Actual Size: 17" x 22"

Colony in Space

What will space stations and orbiting colonies of the future look like? Artist Rick Sternbach provides an ingenious answer in his painting of a mile wide space station wheeling slowly above the gibbous Earth. Shuttle rockets near the station's hub bring ore from the lunar surface for refinement in the station's zero gravity manufacturing center.



Actual Size: 17" x 22"

Pluto

The setting sun glints off a low plain of methane ice on the surface of the smallest and most distant planet, Pluto. The cold and forbidding scene — completely alien to Earth dwellers — comes to life in this rendition by James Hervat. The mysteries of Pluto are brought home to us as we stand and gaze back toward our incredibly distant sun.

ASTRONOMY

making it easier to frame, or suitable for hanging as is.

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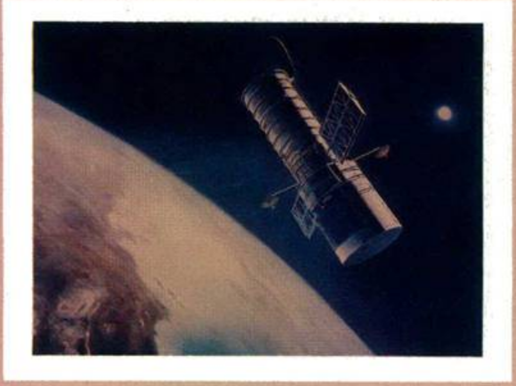

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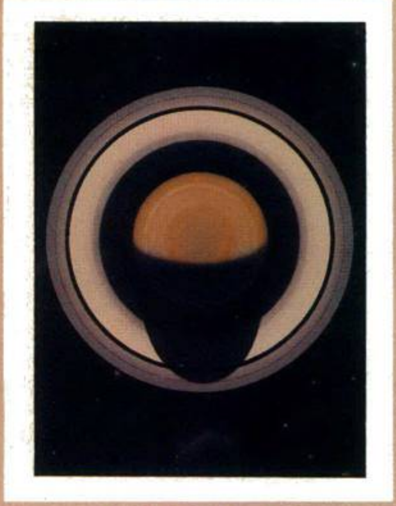
Space Telescope

Painted by John Clark from official NASA blueprints, this poster depicts the Space Telescope — a powerful 94 inch (2.4 meter) aperture telescope due to be launched during the early 1980s by NASA's Space Shuttle. This is an accurate depiction of an instrument that will revolutionize man's view of the universe during the decades it remains in operation.



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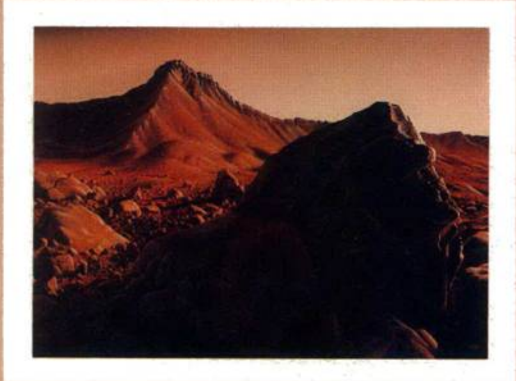
Saturn

In an unusual perspective from above the north pole of Saturn, we can identify the planet's three main rings and their sizes relative to Saturn itself, enabling us to grasp the vast extent of Saturn's ring system. This remarkable painting by Adolf Schaller gives us a view of the planet not obtainable from Earth.

Vallis Marineris

Photographs returned from Mariner and Viking probes revealed for the first time the immensity of Vallis Marineris, the equatorial canyon of Mars. This painting by Adolf Schaller — meticulously transcribed from overhead Viking photos — takes us to the foot of a blanket of landslide rubble in the canyon itself.



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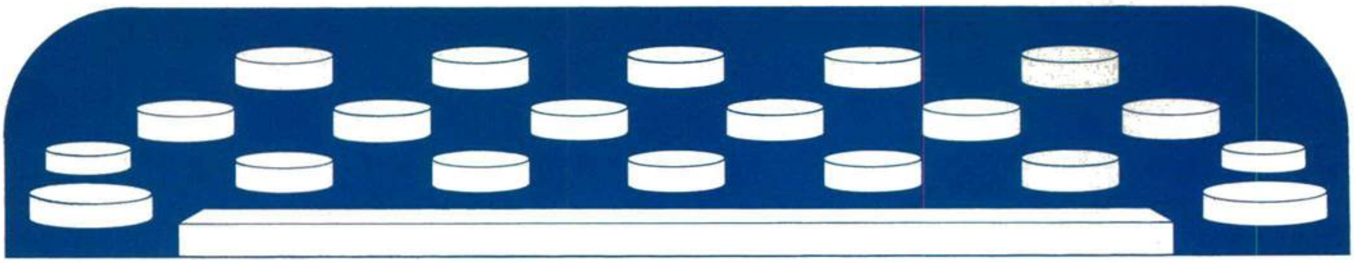

IN FOCUS

Sir / It's possible that my particular level of knowledge and limited achievements in astronomy may be representative of a large segment of your readership. Because of this, I'd like to express a couple of my hopes regarding what I'd like to see in ASTRONOMY.

First, I should mention that I'm 35, married, and have been a subscriber since becoming interested in astronomy in September 1974. With the help of the local club, I ground and polished an eight inch f/5.7 mirror last winter and spring. The finished mirror was mounted in my homemade tube with a machined pipe-fitting equatorial mounting, which I purchased. Since I have no drive, I've been trying afocal astrophotography. When finances permit, I'd like to add a drive, drive corrector, guidescope (I have a four inch Newtonian I plan to use), and all the other miscellaneous items needed for astrophotography.

I really appreciate your full page and half page color amateur astrophotos. But I wish you would include — with the captions or elsewhere — a little information about the equipment and technique used. For example, when I look at those pages I wonder if they were made at prime focus or just how. I would like to know if the scope was a portable one or on a fixed pier, and how the excellent guiding was achieved. This sort of information would help me appreciate the finished product as well as offer me help in my own desires to someday be able to produce similar results.

Let me wind up by making a comment on Richard Berry's article ("Cleaning Your Telescope Mirror") in the December 1976 issue. I tried cleaning my diagonal mirror. Even though I used grocery-store-variety distilled water and rinsed with it several times, I was unsuccessful in getting the mirror to dry without water spots. Successive washings change the placement of water spots, but I can't eliminate them. I even tried a rinse with an ammonia based window cleaner before the final rinsings, but see no difference. What should I do?

DAVID OGRON
Green Bay, Wisc.

Mr. Ogron / Okay, readers! When you submit pictures, try to include a bit more information than you usually do — especially tips that could help a fellow astrophotographer. Even if we don't have space to include information in the photograph caption, we'll save them for "how to" articles in Photography in Astronomy. By the way, Photography in Astronomy will soon start a series on various systems you can use for astrophotography, such as telephoto lenses, Newtonian prime focus, projection, etc. Equipment Atlas is also getting geared up to provide some real information on telescopes and drives, setting up, alignment, adjustment, and so on. However, due to space limitations, it'll take about one year to really cover them all. So keep an eye on these departments, and keep the beautiful photographs coming in. By the way, don't forget that ASTRONOMY pays $10.00 for each color photo we publish, and $7.50 for each black and white print.

After reading of your problem with cleaning the diagonal mirror, Mr. Ogron, we suspect that your distilled water is either contaminated or not really distilled. Distilled water won't leave spots when it dries — period! Here's how to get water spots off easily: After rinsing for the last time, use a piece of plastic tubing about two feet long to "chase" each remaining droplet off the mirror surface by blowing. Be very careful not to spit down the tube — you can practice by blowing droplets off a water glass first. We're surprised that your water was not clean; we've tried this technique with distilled water purchased at a grocery store here in Milwaukee.

By the way, Chicago Optical Supply Company (227 E. Ontario St., P.O. Box 11309, Chicago, IL 60611) sells a mirror cleaning detergent called "Krystolux", which does a much better job than ordinary detergent. One of their two ounce bottles could easily do a dozen mirrors.

Sir / I fully agree with John Harmon ("Observing From the City", ASTRONOMY, March 1977) that city observing can be quite rewarding, even though it's more difficult. Most of my observing over the past four years was carried out at the Springfield (Mass.) Science Museum, located in the heart of the city, using a 20 inch reflector and smaller instruments.

The size of the reflector didn't give me too much of an advantage over smaller telescopes, and often the 20 inch was rivaled by a three inch refractor from the standpoint of clarity and contrast. When observing with the 20 inch telescope, I was looking through a wider column of atmosphere, which caused increased turbulence. This seems to be the major shortcoming of large telescopes in the city. Of course, background illumination also caused problems.

Despite pollution and city lights, I've spent hundreds of hours locating and observing celestial objects. One night in 1973 was remarkably clear between midnight and dawn; I observed Mars for quite a while, and was rewarded by several short periods during which the planet suddenly became crystal clear and full of detail. From the city, these periods of good seeing are few and far between, but they do exist.

The Crab and Owl nebulae proved to be my most difficult observations. They were just barely visible over the background haze, although the contrast was improved by slowly moving the telescope back and forth while observing the object. In general, diffuse objects are much more difficult from the city than stellar objects.

In 1974 there was a stretch of good sky conditions during which I was able to observe Pluto on several occasions. It was just on the verge of visibility in the 20 inch. It would sparkle for a few seconds, and then become lost in the turbulence. Even so, it was an exciting experience to see that frozen world for the first time.

I'm convinced that even from rather large cities, all the Messier objects are within range of the diligent observer. And after observing from the city, you can really appreciate the magnificent black sky and sparkling heavens out in the country.

RICHARD SANDERSON
West Springfield, Mass.

Mr. Sanderson / Thank you very much for your letter. It should help stimulate activity among the ranks of ASTRONOMY readers who are city dwellers. We'd be interested in hearing from other "urban observers" about their experiences.

ASTRONOMY

The World's Most Beautiful Astronomy Magazine

June 1977 Vol. 5, No. 6

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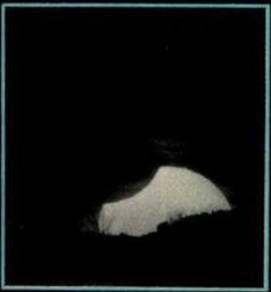
4 IN FOCUS
6 GAMMA RAYS AND THE ORIGIN OF COSMIC RADIATION
by Trevor Weekes
18 SKY ALMANAC
Venus and Mars . . . Together Again
20 PLANET FINDER — JUNE 1977
26 A SECOND RINGED PLANET
by Mary Jane Lamers
28 EQUIPMENT ATLAS
Beginning With Your Telescope
by Mary Jane Lamers
42 GAZER'S GAZETTE
Observing With Binoculars
by Henry J. Phillips
47 Watch A Stellar Eclipse
by E. Ray Grasshoff
51 PHOTOGRAPHY IN ASTRONOMY
Spectroscopic Films in Color
54 ASTRONOMY REVIEWS
60 ASTRO-MART
65 GUIDE TO BACK ISSUES
67 ASTRO-NEWS
73 JUNE STAR DOME
by James Mullaney and Henry J. Phillips
75 Close-Up on the Ophiuchus Region



Cover

Much of ASTRONOMY this month is devoted to the joys of observing — getting outside and seeing for yourself some of the marvelous objects and events of which you've read or seen photos. Do you have a new telescope? Equipment Atlas will tell you how to enjoy it to its fullest capacity. Would you like to look at the sky with your birdwatching binoculars? You can find out what you'll see with them in Gazer's Gazette. Explore the Ophiuchus region of the sky with the help of Star Dome, and if you're ready for a new challenge, why not try watching eclipsing variables? There's always something in the sky for everyone to see. Our cover shows the rising, partially eclipsed sun of Dec. 13, 1974. This fall (Oct. 12), residents of most of North America will be able to see a similar event — without elaborate equipment! The photo is a 1/60 second exposure on Kodachrome-II, shot through a homemade telephoto system. Photograph by Ernest W. Piini.

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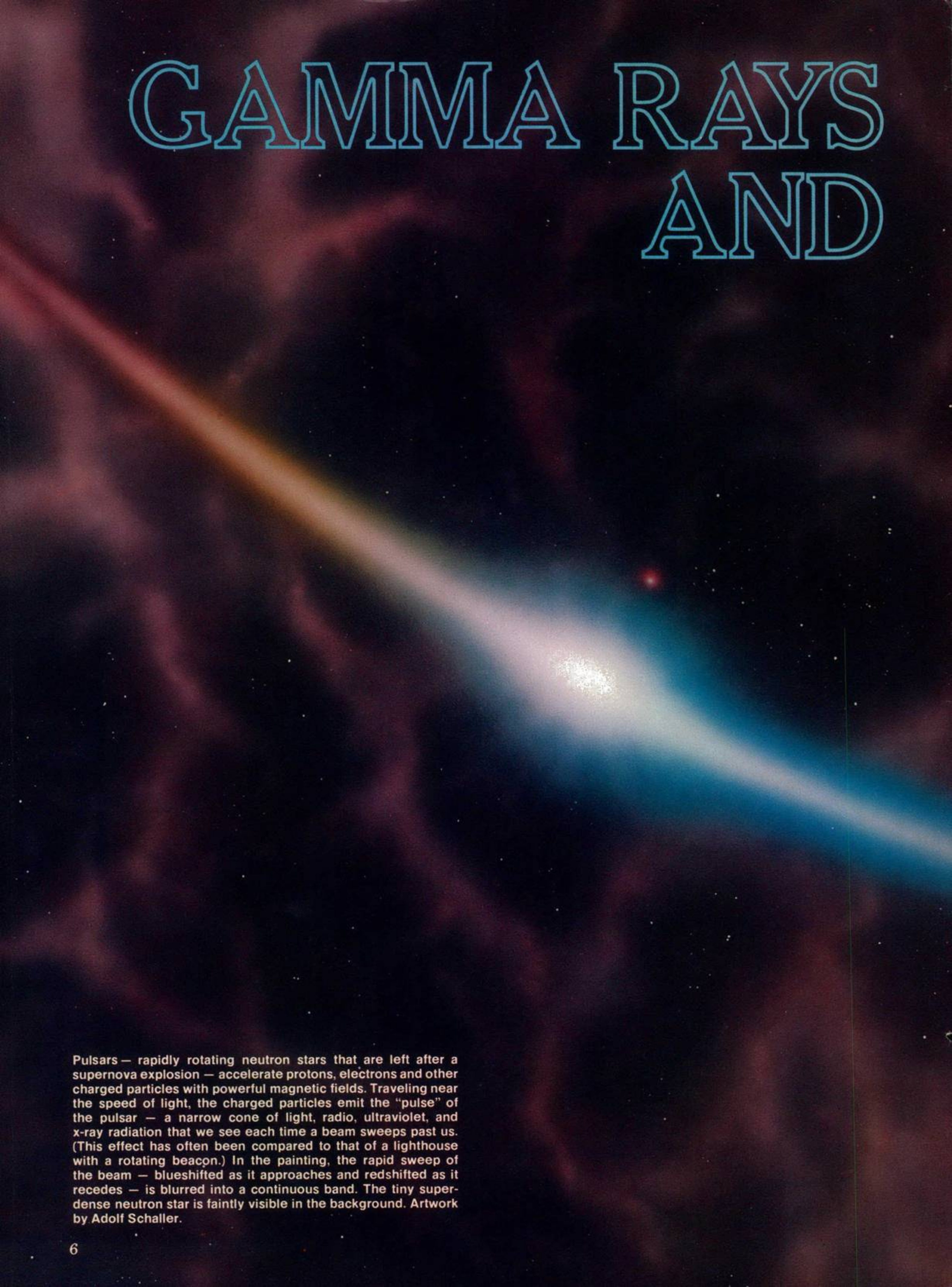
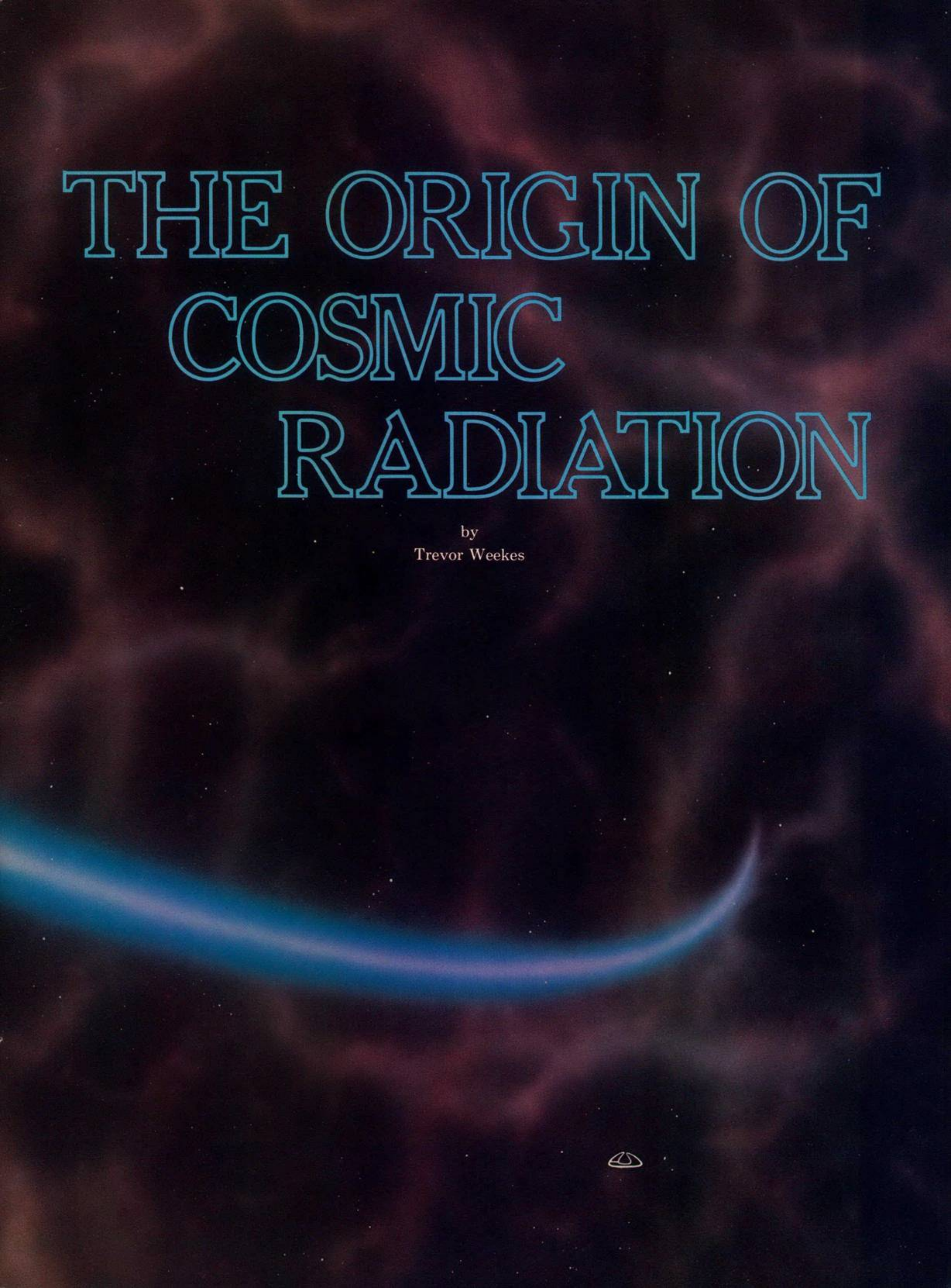
GAMMA RAYS AND

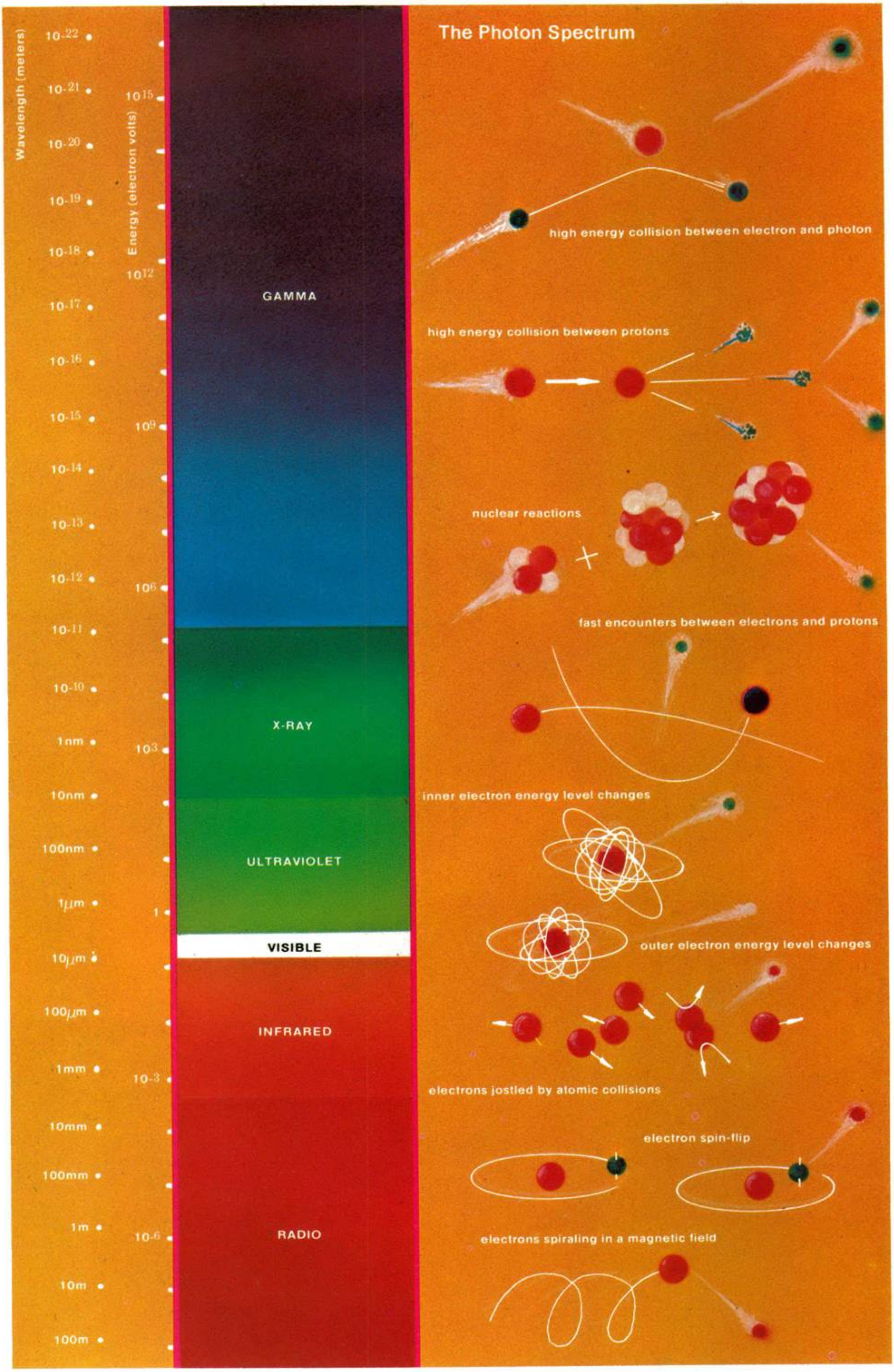


Pulsars — rapidly rotating neutron stars that are left after a supernova explosion — accelerate protons, electrons and other charged particles with powerful magnetic fields. Traveling near the speed of light, the charged particles emit the "pulse" of the pulsar — a narrow cone of light, radio, ultraviolet, and x-ray radiation that we see each time a beam sweeps past us. (This effect has often been compared to that of a lighthouse with a rotating beacon.) In the painting, the rapid sweep of the beam — blueshifted as it approaches and redshifted as it recedes — is blurred into a continuous band. The tiny superdense neutron star is faintly visible in the background. Artwork by Adolf Schaller.

THE ORIGIN OF COSMIC RADIATION

by
Trevor Weekes





The Photon Spectrum

Wavelength (meters)
10^{-22}
10^{-21}
10^{-20}
10^{-19}
10^{-18}
10^{-17}
10^{-16}
10^{-15}
10^{-14}
10^{-13}
10^{-12}
10^{-11}
10^{-10}
1nm
10nm
100nm
1μm
10μm
100μm
1mm
10mm
100mm
1m
10m
100m
Energy (electron volts)
10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
1
10^{-3}
10^{-6}
GAMMA
X-RAY
ULTRAVIOLET
VISIBLE
INFRARED
RADIO
high energy collision between electron and photon
high energy collision between protons
nuclear reactions
fast encounters between electrons and protons
inner electron energy level changes
outer electron energy level changes
electrons jostled by atomic collisions
electron spin-flip
electrons spiraling in a magnetic field

Discoveries made during the last decade have apparently solved one of the great puzzles of astrophysics — the origin of cosmic radiation. *Gamma ray astronomy* — a new branch of astronomy — has provided compelling evidence that the bulk of this high energy radiation comes from within our own galaxy.

For over 60 years, scientists have known that Earth's upper atmosphere is bombarded by very high energy particles. Careful study has shown that the radiation consists mainly of fragments of atoms [protons, alpha particles (helium nuclei) and heavier nuclei], but that it also includes gamma rays, electrons and more exotic particles such as neutrinos. Since the arrival directions are essentially *isotropic* (that is, they arrive from all directions), astronomers have deduced that the radiation cannot originate in our solar system; it is therefore called the *Cosmic Radiation*. While gamma rays are only a part of the total cosmic radiation we receive, we shall see that they contain very important clues about the origin of all cosmic radiation.

(For the purposes of this article, the term cosmic radiation refers to radiation reaching Earth from all parts of the electromagnetic spectrum, including x-rays, infrared, visible light, ultraviolet and gamma rays. The term Cosmic Radiation refers only to radiation in the very high energy region of the spectrum: gamma rays and cosmic particles.)

The total energy we receive from cosmic rays is considerable; it is believed to be about the same amount of energy that we receive as light from all stars other than the sun. However, it is the distribution of the energy, rather than the total energy, that makes Cosmic Radiation of such great interest. Some Cosmic Radiation particles have enormous energies, one trillion (10^{12}) times greater than the most energetic particles emitted by atoms in radioactive decay or nuclear fission. The question astrophysicists had to answer was, "How could anything natural be given so much energy?" Because of the high energies, cosmic radiation has also been intensively studied by elementary particle physicists who have used it to investigate high energy nuclear interactions. But, as manmade particle accelerators were improved, the emphasis shifted to studying Cosmic Radiation for itself.

The high energies suggest that Cosmic Radiation is tied in with the most energetic processes and objects in the universe; thus the search for the source of the radiation has been an important one for astrophysicists during the last two decades.

Since the 1930s, nuclear physicists have devoted much of their efforts to the development of machines called particle accelerators. Using giant synchrotrons — the so-called atom smashers — they have succeeded in accelerating particles to very high energies, about 100 billion times the energy of a photon of visible light. These great machines (some of them in excess of a mile in diameter) are triumphs of modern precision engineering; using a combination of electric and magnetic fields, the atomic particles are guided on a well-defined path as their energy is increased with each passage through the machine. By collision at high energies, physicists learned more about the nuclei of atoms. However, these giant modern machines are only capable of accelerating particles to energies that are one billion times *less* than the maximum energy observed in Cosmic Radiation!

If cosmic ray particles were accelerated by a similar mechanism, then it seemed likely that somewhere in the universe there had to be one or more "particle accelerators" of tremendous precision, efficiency and power. But until recently — say the last 15 years — our impression of the universe from optical and radio astronomy was mostly one of chaos. While we did observe energetic processes, they were only in the rather rare explosive and catastrophic events. Nowhere was the precision engineering that we knew was necessary to continuously generate the many high energy particles observed.

The fact that the source of Cosmic Radiation must simultaneously contain great energy and great order made its nature extremely intriguing. Hitherto unknown physical processes could be involved, or at least couldn't be eliminated. Hence the search for cosmic accelerators occupied many theoretical and observational physicists. In the last few years, the solution has finally appeared in sight — mainly from gamma ray astronomy.

The gamma ray region of the electromagnetic spectrum is distinguished by two characteristics: the high energy of the individual photons and the very broad energy range involved. The upper and lower boundaries of the gamma ray energy range is a matter of definition; most x-ray and gamma ray experimenters seem to regard one MeV (one million electron volts) as the dividing line between the two disciplines. The upper end of the spectrum has not yet been determined, but it may extend up to the highest energies observed in the cosmic radiation (10^{20} eV = 100 quintillion eV).

Since the gamma ray region is as broad as the regions of the radio, microwave, infrared, visible, ultraviolet and x-ray regions combined, it may seem strange that we do not hear more about it. But the truth is that until recently, gamma ray astronomy has produced few observational results; it is only in the last few years that there were any significant results to report! Even today it is possible to summarize all the important observational results in just a few pages.

Gamma rays are electromagnetic radiation, as are light, radio waves, x-rays, and ultraviolet and infrared light. But gamma rays are distinguished by having far more energy per photon and a very much shorter wavelength. At right, the processes that produce each type of radiation are shown. For radio waves and infrared light, electrons are mildly jostled. For light and ultraviolet light, electrons are vigorously bounced around the atom, while for x-rays and gamma rays, the nuclei of atoms and elementary particles are violently perturbed.

What Are Gamma Rays?

by

Gerrit L. Verschuur

Radiation fills the universe around us. It consists of far more than meets the eye; we only experience light waves from objects (both on Earth and around us in space) because our eyes are sensitive to these waves. Light is one form of electromagnetic radiation, but it's a tiny part of the total spectrum of electromagnetic waves. In the last two decades, astronomers have found it immensely important to study other forms of electromagnetic waves from space, including radio waves, infrared light, ultraviolet and x-rays.

These radiations differ from each other in their wavelengths and energies. Radio waves have lengths of many meters to centimeters, and infrared radiation, a few millimeters to hundredths of a millimeter long. Light waves are measured in billionths of a meter (green light has a wavelength of about 550 nanometers). Ultraviolet radiation is shorter than light waves, with wavelengths of a few hundred down to ten nanometers. Even shorter are x-rays ranging in wavelength from ten to tenths of a nanometer. (An atom is about 1/10 nanometer in diameter.) This means that x-rays can interact strongly with individual atoms. X-rays are thus a powerful probe for studying the structure of atoms.

But there are other radiations whose wavelengths are even shorter than x-rays; these are the gamma rays. Their wavelengths range from hundredths to millionths of nanometers. However, at such short wavelengths it is usually more convenient to consider the energy of the photons rather than the actual wavelength.

A property of matter and radiation is that you can interchangeably think of them as either waves or as particles. The particle, usually called a photon, has an energy that is inversely related to its wavelength. Conversely, radiation of a given wavelength can be thought of as being a particle or photon of some specific energy. Experiments can be designed to demonstrate that either of two ways of viewing matter and radiation are valid. However, no single experiment has ever been performed that proves both properties can exist at the same time.

The shortest wavelength photons have the highest energies. In the case of gamma rays, which can also be thought of as photons with a very short wavelength, they have enormous energies. Astronomers usually refer to gamma rays in terms of their energies rather than using wavelengths, mainly because energy is easier to measure. The units of energy used are measured as electron volts of energy. Thus, gamma rays range in energy from hundreds of kilovolts (one kilovolt is 1,000 volts) to many millions of electron volts (megavolts). The jargon used by gamma ray astronomers is therefore very different from any used by optical astronomers who talk about Angstrom units, and the radio astronomers, who refer to radio waves in terms of centimeters.

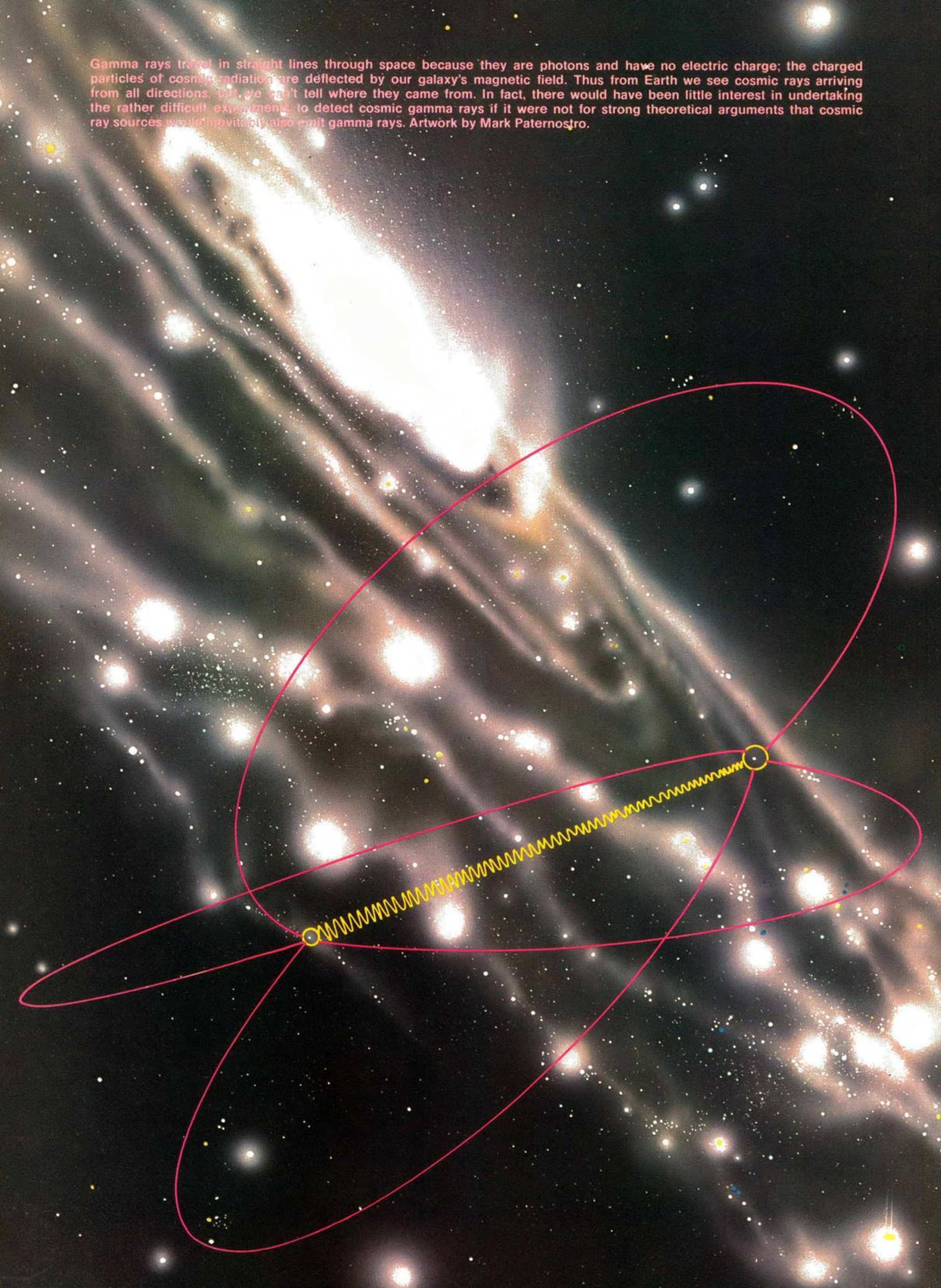
The important point to remember is that the highest energies are also the shortest wavelengths and, in the case of gamma rays, the shortest wavelengths involved are much smaller than the diameter of the atom. In fact, gamma ray wavelengths are nearly as small as the diameter of electrons.

Although gamma rays are electromagnetic radiation and have all the familiar properties of light, they are unusual in some respects. Because of the large energy associated with each photon, it is convenient to treat them as particles, just as we occasionally treat light as particles. In fact, for all practical purposes, gamma rays can be considered part of the particle Cosmic Radiation, but differing because they have no mass and no charge. It is this lack of charge that makes the gamma ray component fundamentally important in cosmic ray studies.

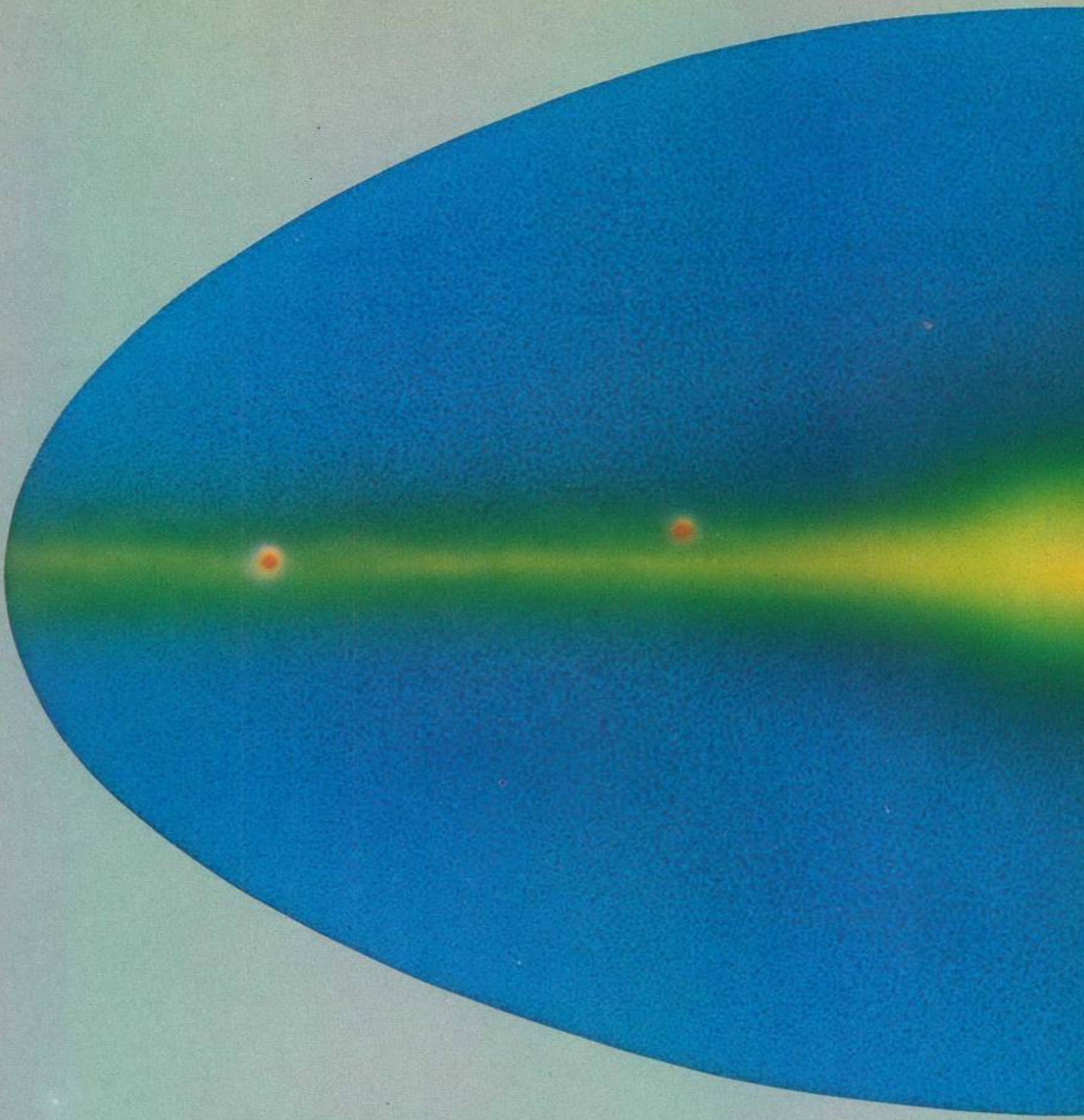
Being uncharged, gamma rays are the only type of cosmic radiation that comes to us *directly*. The galaxy — and indeed intergalactic space — contains magnetic fields; they are weak, but over large distances all electrically charged particles are bent or deflected from their original paths by these fields. When we receive them, we don't know where they come from. Like light from the sun on a foggy Earth day, cosmic rays come from all directions, even though they may have originated from a single source. But gamma rays are unaffected by the weak intergalactic and galactic magnetic fields; thus we can "see" where they come from.

What are the results? As we mentioned, the long years of effort by gamma ray experimenters are finally bearing fruit, and we now have the first gamma ray map of the sky! Although not all of the sky has been scanned with equal sensitivity, the map (based mostly on the results of the SAS-2 and COS-B satellites) illustrates the major features. Of course, as the sensitivity of the detection techniques improves, many more features will be discovered. As we shall see, even these early results are keeping the theoretical astrophysicists busy since there is not a single feature on the map that yet has a full theoretical explanation!

It is immediately obvious that *the bulk of the gamma ray emission is coming from regions along the galactic equator and the center of the Milky Way.* This emission is not uniform, and there is a general concentration toward the direction of the galactic center; there are also several well-defined "point sources". A general diffuse background of gamma rays is evident above and below



Gamma rays travel in straight lines through space because they are photons and have no electric charge; the charged particles of cosmic radiation are deflected by our galaxy's magnetic field. Thus from Earth we see cosmic rays arriving from all directions, but we can't tell where they came from. In fact, there would have been little interest in undertaking the rather difficult experiments to detect cosmic gamma rays if it were not for strong theoretical arguments that cosmic ray sources would inevitably also emit gamma rays. Artwork by Mark Paternostro.



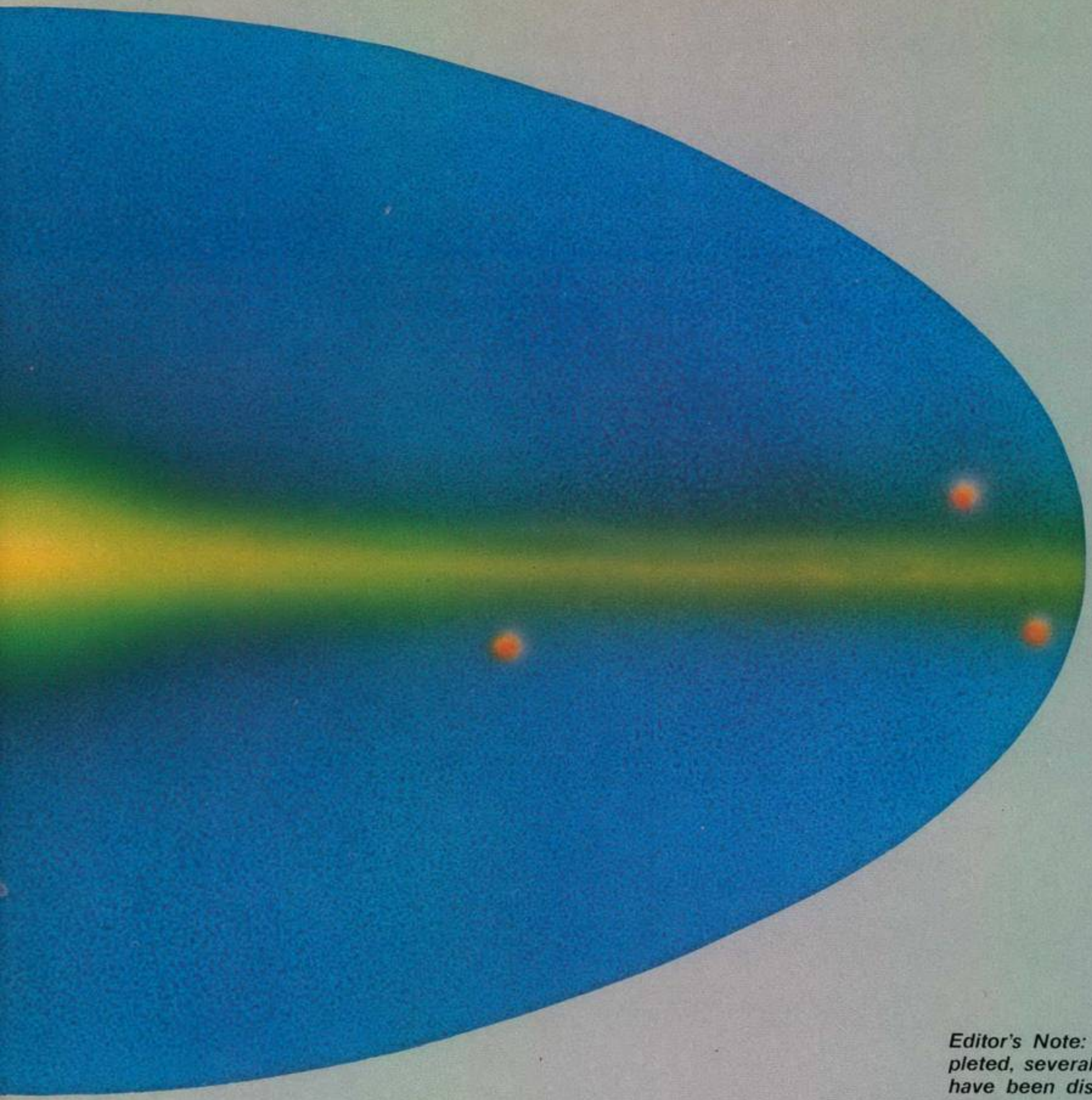
the plane of the galaxy. To the limit of the present observations, *the diffuse background gamma ray flux appears to be uniform in all directions.*

The problem that an astronomer encounters in studying our galaxy when he is embedded in it is analagous to that of a cartographer who wants to draw a map of a forest but is surrounded by trees and unable to move from his desk. If only he could rise above the trees, he would easily see the general outlines of the forest, places where the trees are densest, the position of roads, fire lanes and other significant features. But if he is confined to one place on the ground, he can only make an estimate of his immediate surroundings; beyond that, he is completely lost.

The galactic astronomer faces a similar problem: His information about the galaxy is extremely limited. From the study of distant galaxies, he can surmise that the galaxy has a spiral structure and find some confirmation from observation of nearby stars and gas, particularly at radio wavelengths. He cannot "see" the distant parts of the galaxy, however, so he is in the irritating position of having a better idea of the structure of other galaxies (such as M-31 in Andromeda) than his own.

Gamma ray astronomy provides a new opportunity for studying the spiral arm structure of the galaxy. Since the distribution of gamma rays with galactic latitude correlates with the nearby spiral arms, gamma ray studies may reveal more features of these arms and perhaps allow astronomers to explore the hitherto hidden arms.

One of the most problematic aspects of theories concerning cosmic ray origins is whether they come from within or outside our galaxy. If they come from within, the total energies in the form of cosmic rays in the universe must be very much less, but the acceleration process within the galaxy must be a remarkably efficient particle accelerator. If the universe is filled with high energy cosmic rays (that is, if they have an extragalactic origin), then they can originate in some exotic source such as



Editor's Note: Since this map was completed, several more gamma ray sources have been discovered by the European Space Agency satellite COS-B. They lie in the galactic plane, and have not yet been identified.

Above is a map of the gamma ray sky. Gamma ray telescopes detect the disk and center of our galaxy (shown in yellow for clarity); they show a general background from all over the sky (shown in blue), and a number of point sources which are shown as starlike objects. The next generation of gamma ray telescopes will reach much fainter point sources and add more detail to the galaxy — perhaps enough to map its spiral arms by their gamma rays.

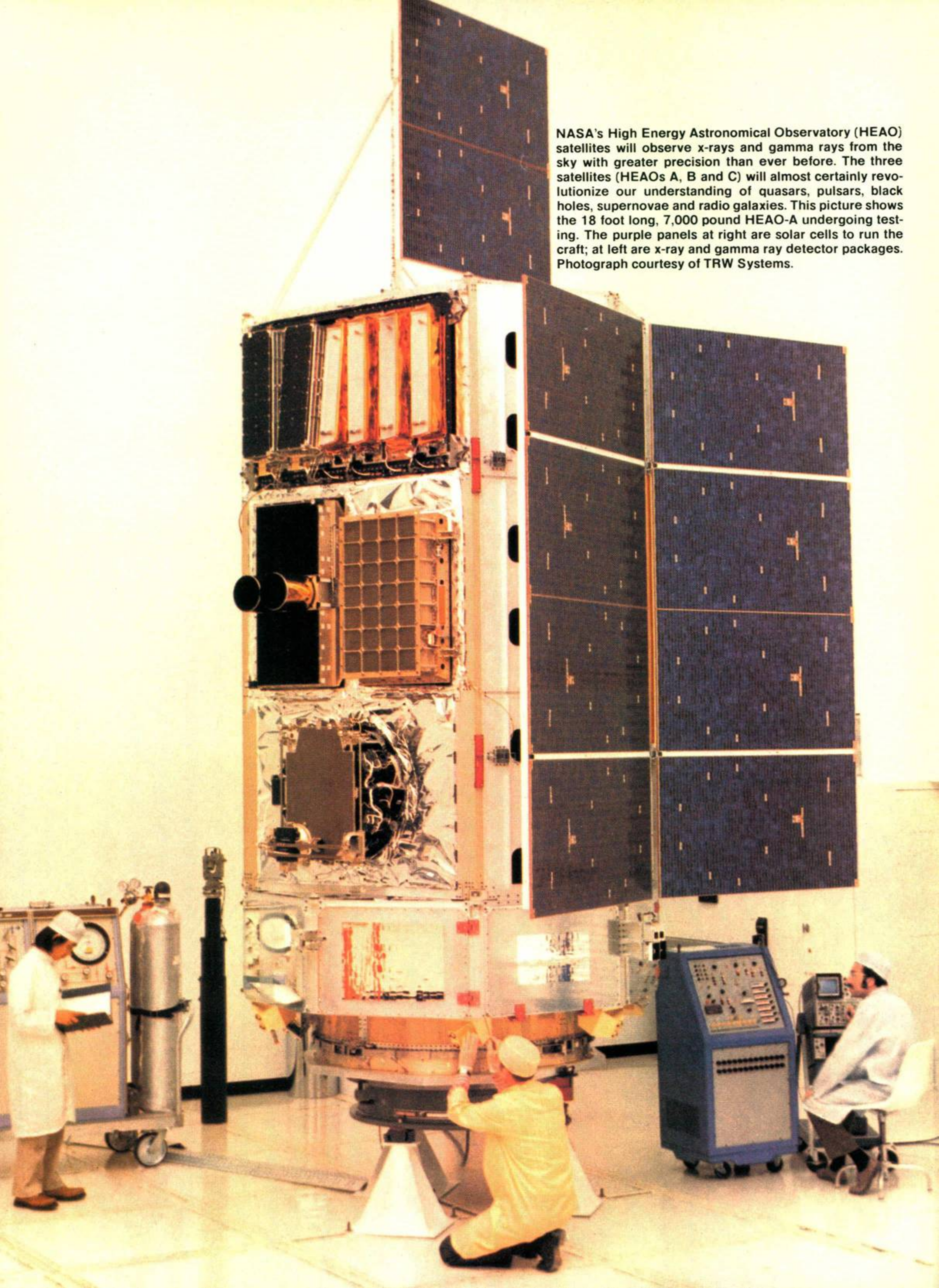
quasars — which we know so little about that it is easy and tempting to speculate that they are the particle accelerators we are seeking.

Gamma rays are expected from the galactic plane because of the interaction of cosmic ray nuclei with interstellar gas. If both cosmic rays and interstellar gas had a uniform distribution within the galaxy, then the gamma ray flux would also be uniform. Since this is *not* the case and we see the arms in gamma rays, the cosmic rays and interstellar gas are concentrated along the arms. While this was expected for the interstellar gas, it is the first information that astronomers have had on the cosmic ray distribution outside our solar system. It seems likely then, considering the dominant role of the galaxy on cosmic ray distribution, *that the source of the cosmic rays lies within the galaxy.*

The small (but not negligible) gamma ray flux away from the galactic plane also has bearing on cosmic ray origins. Since this flux appears to be uniform, it most likely originates outside the galaxy. If this is the case, then it could come from the collision of cosmic rays with intergalactic gas. Our knowledge of both the density of intergalactic gas and intergalactic cosmic rays is extremely poor; a reasonable figure for the former would be one hydrogen atom per 100,000 cubic centimeters. If the cosmic ray density that we observe on Earth were the same throughout the universe, then we would detect more gamma rays than we have observed.

From this we can again conclude that *the cosmic rays are most likely confined to the galaxy,* although if the terrestrial cosmic ray density did

GAMMA RAY *continued on page 16*



NASA's High Energy Astronomical Observatory (HEAO) satellites will observe x-rays and gamma rays from the sky with greater precision than ever before. The three satellites (HEAOs A, B and C) will almost certainly revolutionize our understanding of quasars, pulsars, black holes, supernovae and radio galaxies. This picture shows the 18 foot long, 7,000 pound HEAO-A undergoing testing. The purple panels at right are solar cells to run the craft; at left are x-ray and gamma ray detector packages. Photograph courtesy of TRW Systems.

Gamma Ray Telescopes

by
Trevor C. Weekes

In some ways gamma rays are extremely easy to detect. Because of their particle character, they can be detected by any of the conventional particle detectors that nuclear physicists use in the laboratory. The gamma ray transfers all or part of its energy to electrons in the detector medium, and it is these electrons that are detected.

In other ways the detection of gamma rays is extremely difficult. As with much of the rest of the electromagnetic spectrum, gamma rays must be detected above Earth's atmosphere. For gamma rays, the atmosphere is completely opaque — equivalent in shielding to one meter (3.38 feet) of lead. Although individual gamma ray photons have high energies, the number of gamma rays is small; so, for a reasonable rate of detection, the detectors must have large areas and be exposed for long periods.

The most troublesome detection problem arises from the background of charged cosmic rays. It's ironic that cosmic rays, which are the very reason for so much interest in the study of gamma rays, are the ultimate limitation in their detection. Since gamma rays are detected by particle detectors, these detectors will also be triggered by charged cosmic rays of comparable energy. Charged cosmic rays are 1,000 to 10,000 times more numerous than gamma rays of the same energy, making the unique detection of the latter with a simple detector almost impossible! In practice, therefore, sophisticated detector systems which preferentially detect gamma rays must be used.

This is achieved in two ways. Since gamma rays have greater penetrating power than their charged particle counterparts, the main detector can be surrounded by a thin detector — one which is virtually transparent to gamma rays but which almost always registers the passage of a charged particle. By operating this "shield" detector in anticoincidence, gamma ray events can be preferentially selected.

At energies greater than one MeV, the gamma ray photon interacts with matter predominately by pair production (the gamma ray disappears and a pair of electrons takes its place). It is these electrons (one positive and one negative) that ionize the detector medium and enable the gamma ray to be registered. A nonionizing particle (the gamma ray), which produces two ionizing particles, is an unusual kind of interaction and, if the detector allows some visible representation of the tracks of the particles, it enables the incoming particle to be positively identified as a gamma ray. This can be achieved in a number of ways, but the most practical detector for gamma ray astronomy has been the spark chamber.

A spark chamber consists of a series of thin metal plates separated by a gas such as neon. High voltage (10,000 volts) is applied to alternate plates so that the passage of an ionizing particle through the gas causes a spark to jump between adjacent plates. A gamma ray will produce a pair of electrons in one of the plates, and the electron pair will be apparent as a pair of diverging spark tracks. The tracks can be photographed or recorded digitally and the picture reconstructed later. The entire spark chamber is surrounded by an anticoincidence shield detector or plastic scintillator.

The principal advantage of this type of detector is that it enables the selection of characteristic gamma ray events. An angular resolution of a few degrees can be achieved in a total field of view of ±30 degrees. By measuring the length of the electron tracks or by use of auxiliary detectors, some energy resolution can be achieved. An important disadvantage of this type of detector is that it has a considerable dead time (the interval after the detector has triggered and before it is ready to register another event). This effectively limits spark chambers to areas of less than one square meter.

Most of the gamma ray results recorded to date have come from balloon or satellite experiments. Balloon experiments have been limited by the duration of the flight (about eight hours) and the inability of the balloon to get completely clear of the atmosphere (to avoid the troublesome background of secondary gamma rays arising from interaction of cosmic rays with air molecules). But balloons have the ability to fly very large detectors, and balloon experiments have the flexibility that comes with short flights and recoverable payloads.

Although the Explorer and OSO satellites gave some glimpse of the gamma ray sky, our most detailed picture has come from the SAS-2 and COS-B satellites. SAS-2 was launched in November 1972 by the Goddard gamma ray group; in its eight months of life, it surveyed 55 percent of the sky and established the principal features of gamma ray distribution in the galaxy.

COS-B is the result of European collaboration. Launched in August 1975, it is still operating. Its sensitivity is similar to that of SAS-2, and it is hoped that it will eventually survey the entire sky.

At energies some 1,000 times greater than that covered by these spark chamber experiments, it is possible to do gamma ray astronomy from the ground. The atmosphere is still essentially opaque to gamma rays, but now the individual gamma ray energies are sufficiently high that they produce an effect in the atmosphere that can be detected at ground level. The gamma ray interacts with an air molecule high in the atmosphere and produces an electron pair. The electrons are so energetic that they interact again, producing more photons and electrons, and an electromagnetic cascade develops. Eventually, all the energy in the particles is absorbed. However, since all the particles in the cascade are traveling close to the speed of light, they generate an optical shock wave (Cerenkov radiation), which continues on to ground level as a disk of faint blue light. The disk has a diameter of 200 meters (660 feet) and the light pulse lasts for 10 billionths second. It can easily be detected with a simple light receiver at a dark site under a clear moonless sky. The 10 meter reflector on Mount Hopkins is one of the most sensitive instruments used in this energy region. As at lower energies, the sensitivity is limited by the charged cosmic ray background; the Cerenkov light detectors are designed to optimize their detection of light from gamma ray induced cascades, rather than charged cosmic ray induced cascades.

At even higher energies, sufficient particles in the cascades penetrate to mountain altitudes so that they can be detected with arrays of particle detectors (air shower arrays). However, it is difficult to say with certainty which of the large air showers that are detected is caused by a gamma ray.

GAMMA RAY *continued from page 13*

extend somewhat beyond the galaxy, it would still be consistent with gamma ray observations.

Of course, the diffuse background could be produced in other ways; it is these possibilities that have cosmologists excited. Because of the penetrating power of gamma rays, those that are observed could have traveled great distances and hence have been formed very early in the history of the universe. The gamma rays would have been redshifted by large amounts so that the energy distribution of the observed radiation would be quite different than it was when it was generated. Among the possible sources of gamma rays so far suggested are matter-antimatter annihilation reactions, where it is supposed that large quantities of antimatter were produced in the very early stages of the universe.

But while cosmologists may be excited about the results bearing on the early universe, and students of galactic structure intrigued by the discovery of the galactic arm distribution of cosmic rays, cosmic ray physicists have been particularly interested in the gamma ray "point sources". The existence of at least 10 of these is now established. These "gamma ray stars" may well be the hottest and most dynamic objects in the universe, and are most probably fundamental sources of Cosmic Radiation. For all that, only two of them have been positively identified with previously known objects.

The first gamma ray point source to be identified was no surprise: the Crab nebula. The Crab is one of the most prominent objects in the sky at all wavelengths. Observations in the radio, optical and x-ray radiation (which is polarized) from this object led to the suggestion that this supernova remnant was filled with cosmic ray electrons. The exact way in which these high energy electrons would be produced was not known, but if we assumed they existed, then the Crab would be a prime candidate for gamma ray emission.

The Crab has been one of the most intensively studied objects in the universe (see "Supernovae!", April 1977). The Crab is, in every sense, a unique astrophysical "laboratory" with vast information available because of its wide range of electromagnetic radiation. The supernova phenomenon is now fairly well understood; a star which is heavier than the sun will evolve quickly and use up all the nuclear fuel at its center. When the pressure from the thermonuclear burning in the core is no longer strong enough to withstand gravity, the star will collapse. Eventually a stable, but superdense, configuration will be reached for the core, and the implosion will cease. Meanwhile a shock wave propagates outward, carrying with it the outer parts of the star. It is this expanding shell that is the remnant of the star that we observe today as the Crab nebula.

The polarized continuum radiation we observe from the Crab comes from relativistic electrons (those traveling at near the speed of light). But where did *they* get their very large energies? At one time it was believed that cosmic rays were produced in the initial explosion, but it was later realized that the particles could not have survived the 900 years since the explosion.

The discovery of pulsars in 1967 was one of the major astronomical surprises of the last decade. The regularity and the short periods of the pulses pointed to a highly organized and compact object, rather than the vast and chaotic objects astronomy normally dealt with. When a pulsar was discovered in the center of the Crab nebula, it clinched the concept of the pulsar as a rotating neutron star.

In this case, the neutron star is the core of the star that exploded to become the Crab nebula; a star which was more massive than the sun is compressed into an object just five miles (eight kilometers) in diameter. Since the angular momentum must be conserved, what was once a slowly rotating star is now a rapidly spinning (30 times per second) neutron star. The magnetic field which was once about one gauss — about the same as Earth's — is now one trillion (10^{12}) times that amount.

A fast spinning compact object with a huge magnetic field is an ideal system for accelerating particles to very high energies — at last the particle accelerator we've been looking for! There is some debate about the exact way in which acceleration of electrons occurs, but there is no doubt that the pulsar has all the ingredients for a particle accelerator — and the energy lost by the Crab pulsar as its rotation rate gradually decreases is just the amount necessary to supply high energy particles to the nebula.

The ironic fact is that it is only a quirk of nature that pulsars are observable at all. For some reason that we don't understand, there is a "hot spot" on the surface of the neutron star; like the lamp on a lighthouse beacon, we can see it only when it is facing us. If it were not for this "hot spot", the periodic radio pulses would not occur and pulsars would be undiscovered.

Of the 150 pulsars that have now been discovered, the fastest is that in the Crab nebula. It is also the only one observed to pulse at optical and x-ray wavelengths. When 100 MeV gamma rays were detected from the direction of the Crab nebula, it was natural to check them out to see if they are periodic. Not surprisingly, they are; in fact, they come with the same frequency and phase as the radio, optical and x-ray pulses from the pulsar. What is somewhat surprising is that *all* the radiation is pulsed, unlike observations at other wavelengths where only a fraction of the energy is in the pulse.

Ground based techniques have also shown that the Crab pulsar is a gamma ray source at ultrahigh energies of one trillion eV. At high energy, the

Gamma Ray Bursts

by

Gerrit Verschuur

The most unusual source of gamma rays is the infrequent, brief burst of gamma radiation. Each lasts a few seconds, or at most a minute or so, and then switches off again.

Bursts were accidentally discovered in 1973, when the military launched a series of Vela satellites to monitor possible nuclear test explosions on Earth, in space and near the moon. Since nuclear explosions generate gamma rays, these satellites had gamma ray detectors to aid in their monitoring. The Vela satellites were paired (two were located on opposite sides of Earth), therefore providing constant surveillance of space. One day several of the satellites picked up a gamma ray brust. The approximate direction of this burst was obtained from the time delay between the gamma rays reaching the satellites at maximum separation. Hence, from the measured delay between arrival times at the two satellites, the direction could be deduced. Examination of older data and subsequent observations from the satellites revealed eight bursts over a two year period at the beginning of the 1970s.

The way the gamma ray bursts activated the satellite detectors gave clues as to where the sources might be. It became apparent that they were well outside the solar system because the intensities of the bursts recorded by different satellites were the same, implying that the gamma rays must have already traveled a long distance. If they were nearby, then the burst seen by one satellite would be larger than that seen by another.

The source of gamma ray bursts is still not known, and the "directionality" of the satellite equipment is still not good enough to pinpoint the burst positions accurately. It is thought that these sources are in our Milky Way somewhere. Even now, as about one burst per month is found, there are still dozens of theories as to what they may be — though none has met with general approval. Several involve the collapse of matter onto the surface of dense objects such as white dwarfs or neutron stars, which would release tremendous amounts of energy in the form of gamma rays.

Might they be from nuclear explosions on the surface of neutron stars? In this picture you can imagine gas falling from a companion star onto the neutron star; as it piles up, it gets hotter until fusion is ultimately triggered. Thus the hydrogen gas gets converted — first to helium, and then to carbon. At some point there is so much carbon at such a high temperature that the fusion of carbon occurs catastrophically, much as a bomb releases large quantities of energy in a brief flash.

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pulses appear to be more variable than at lower energies.

The second gamma ray source to be identified at 100 MeV energies was the second fastest pulsar (found in the Vela supernova remnant). Again, all the radiation appears to be pulsed, but here the pulse is "out of step" with the pulse at radio frequencies. The other 100 MeV sources may also be pulsars which do not emit lower frequencies such as x-ray, optical, or radio waves. (One of these sources has been tentatively identified with the x-ray source Cygnus X-3 — a binary star system with a 4.8 hour period.)

The significance of the detection of gamma ray pulsations is that it proves without any doubt that there are high energy particles associated with the pulsars. Not only can the pulsar accelerate high energy particles, but it does!

Pulsars are therefore very definitely sources of cosmic radiation; whether they are the only sources, time will tell. But it appears that pulsars in the galaxy can account for all the cosmic rays we see up to energies of 10^{15} eV. Higher energy cosmic rays are probably produced outside the galaxy, perhaps by objects that are analogous to pulsars but on a galactic scale.

As gamma ray observations are improved, we can expect to see more point sources identified in the galactic plane. If some or all of these prove to be pulsars, it may be that pulsars will turn out to be basically cosmic ray sources, with radio radiation only a side product.

Gamma ray astronomy has already provided information about galactic structure, the extragalactic distribution of cosmic rays and the identification of pulsars as cosmic ray sources; it has also provided an exciting surprise. In 1973, the phenomenon of *gamma ray bursts* was discovered. These were completely new and totally unexpected. They have opened up a whole new discipline known as *transient astronomy* at all wavelengths — especially x-ray and gamma ray. However, these sources emit low energy gamma ray bursts, so they are probably not related to the pulsar and neutron star gamma ray sources.

Gamma ray astronomy has progressed slowly in comparison to other branches of the science, but it has now yielded information about the universe we wouldn't have been able to obtain in other ways. As new detectors aboard NASA's High Energy Astronomical Observatories provide new data, we can expect further contributions from this exotic brand of astronomy.

Trevor C. Weekes, a native of Ireland, attended the University College in Dublin. For the last 10 years, he has worked for the Smithsonian Astrophysical Observatory. Stationed for most of that time on Mount Hopkins in southern Arizona, Weekes has served since 1969 as the resident director of Mount Hopkins Observatory. His scientific work has been done in the area of cosmic rays and gamma ray astronomy.

SKY ALMANAC

Venus and Mars... Together Again

If you want to see bright planets during the summer months, you're going to have to get up early. Venus, Mars and Jupiter have all left the evening sky and can be found in the east before sunrise, while Saturn is dropping very low in the west and will be quite hard to spot after mid-July. But if you can manage to crawl out of bed before dawn — or if you're on a camping trip and kept awake by critters sneaking into your sleeping bag — you'll be rewarded by the sight of several shining planets during the early morning hours.

Venus and Mars will be quite close together at the beginning of June, gradually drawing apart as the month progresses. Lovers of planetary conjunctions should find more than enough to satisfy them in this close approach of the two planets, with one much brighter than the other. Keep an eye on Venus during July also, when it will slowly close in on the giant planet Jupiter; the two will reach conjunction with each other on July 30. Both these planetary events will be well worth a photograph or two; your best bet for a good picture is the use of a telephoto lens. And if you obtain a few nice photographs, be sure to send them along to ASTRONOMY.

Mercury

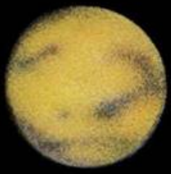
After passing greatest western elongation at the end of May, Mercury swings back in toward the sun during June, gradually becoming lost in the sun's glow. It will be in superior conjunction (behind the sun as seen from Earth) on June 29. On the morning of June 20, Mercury will be less than 1/2 degree from Jupiter. The pair of planets, however, will be situated so close to the sun (only 11 degrees away) — rising less than a half hour before it — that finding them will present some difficulty. Binoculars will help here.

The Eta Carinae nebula (also known as NGC-3372) is the largest and brightest diffuse nebula in the sky — even more so than the Orion. Visible only from latitudes south of +25 degrees, this photo was taken on the island of Aruba, near Venezuela. The large open cluster nearby is NGC-3532. This 40 minute guided exposure was taken through a 350mm lens at f/6.5 on GAF 200 film. In this picture, east is up. Photograph by Don Primi.

Planet Finder

Ⓒ Ceres

June	1	15
R.A.	$12^{h}13^{m}$	$12^{h}20^{m}$
Dec.	+10°51'	+8°46'
Mag.	+7.8	+8.0



Ⓐ Mercury

June	1
R.A.	$3^{h}03^{m}$
Dec.	+13°55'
Mag.	-0.5

Ⓑ Mercury

June	15
R.A.	$4^{h}29^{m}$
Dec.	+20°40'
Mag.	-0.7

Ⓜ Mars

June	1	15
R.A.	$1^{h}41^{m}$	$2^{h}21^{m}$
Dec.	+9°22'	+13°02'
Mag.	+1.3	+1.3

Ⓝ Neptune

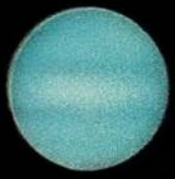
June	15
R.A.	$16^{h}53^{m}$
Dec.	-21°00'
Mag.	+7.7

SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

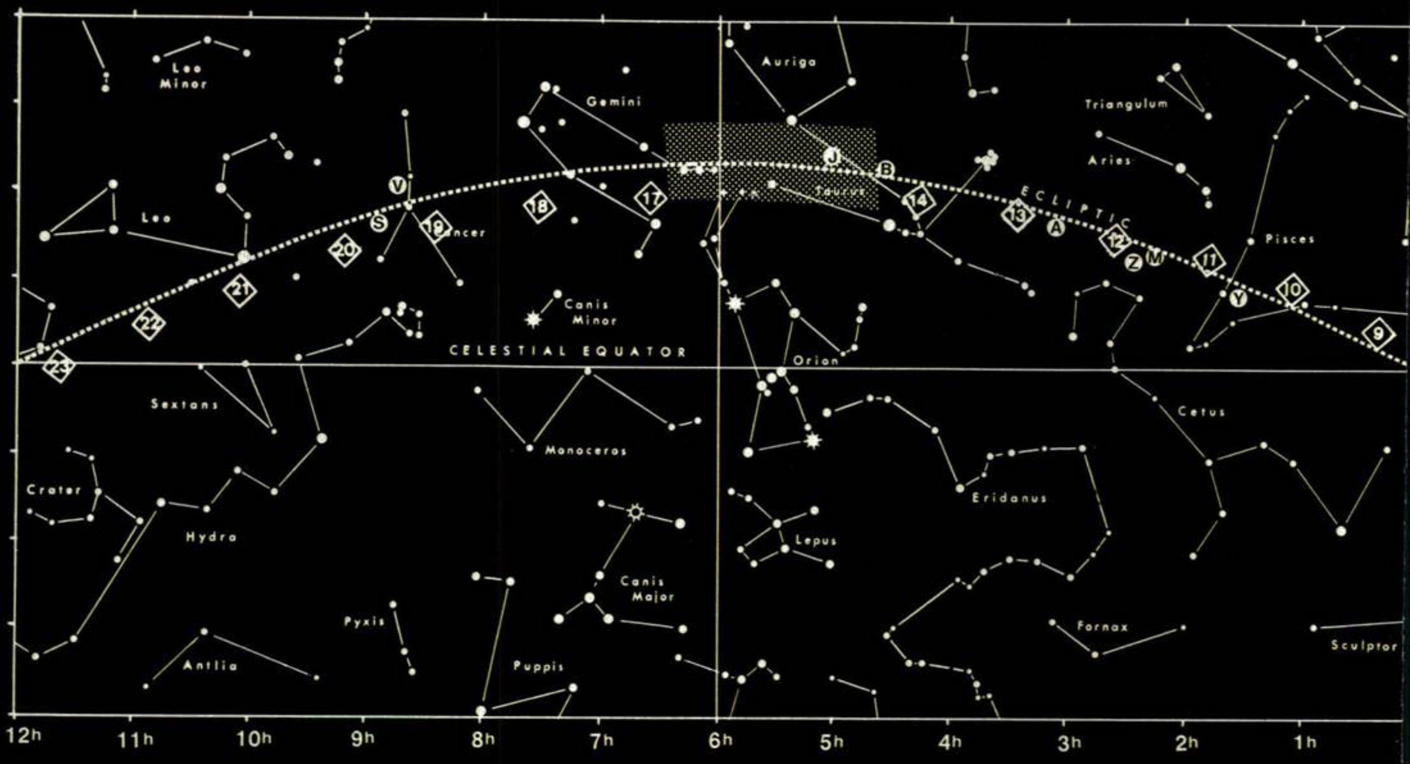
Ⓢ Saturn

June	1	15
R.A.	$8^{h}59^{m}$	$9^{h}05^{m}$
Dec.	+18°03'	+17°42'
Mag.	+0.6	+0.6



Ⓤ Uranus

June	15
R.A.	$14^{h}23^{m}$
Dec.	-13°46'
Mag.	+5.7

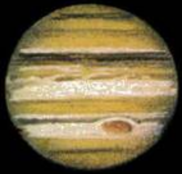

Leo Minor
Auriga
Gemini
Triangulum
Aries
Leo
Taurus
ECLIPTIC
Cancer
Pisces
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Cetus
Monoceros
Crater
Eridanus
Hydra
Lepus
Canis Major
Pyxis
Fornax
Sculptor
Antlia
Puppis
V
S
J
B
A
Z
M
Y
9
10
11
12
13
14
17
18
19
20
21
22
23
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

June 1977

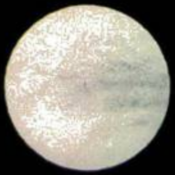
Ⓥ Vesta

June	1	15
R.A.	8h28m	8h52m
Dec.	+23°01'	+21°39'
Mag.	+8.5	+8.6



Ⓙ Jupiter

June	1	15
R.A.	4h46m	5h00m
Dec.	+21°53'	+22°16'
Mag.	-1.5	-1.5



Ⓨ Venus

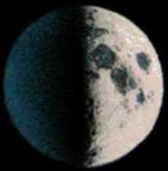
June	1
R.A.	1h40m
Dec.	+8°12'
Mag.	-4.1

Ⓩ Venus

June	15
R.A.	2h30m
Dec.	+11°52'
Mag.	-3.9

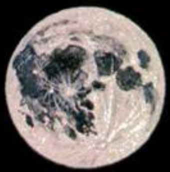
Ⓟ Pluto

June	15
R.A.	13h07m
Dec.	+11°28'
Mag.	+14



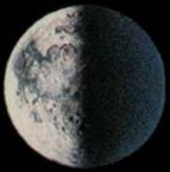
First Quarter

June 24



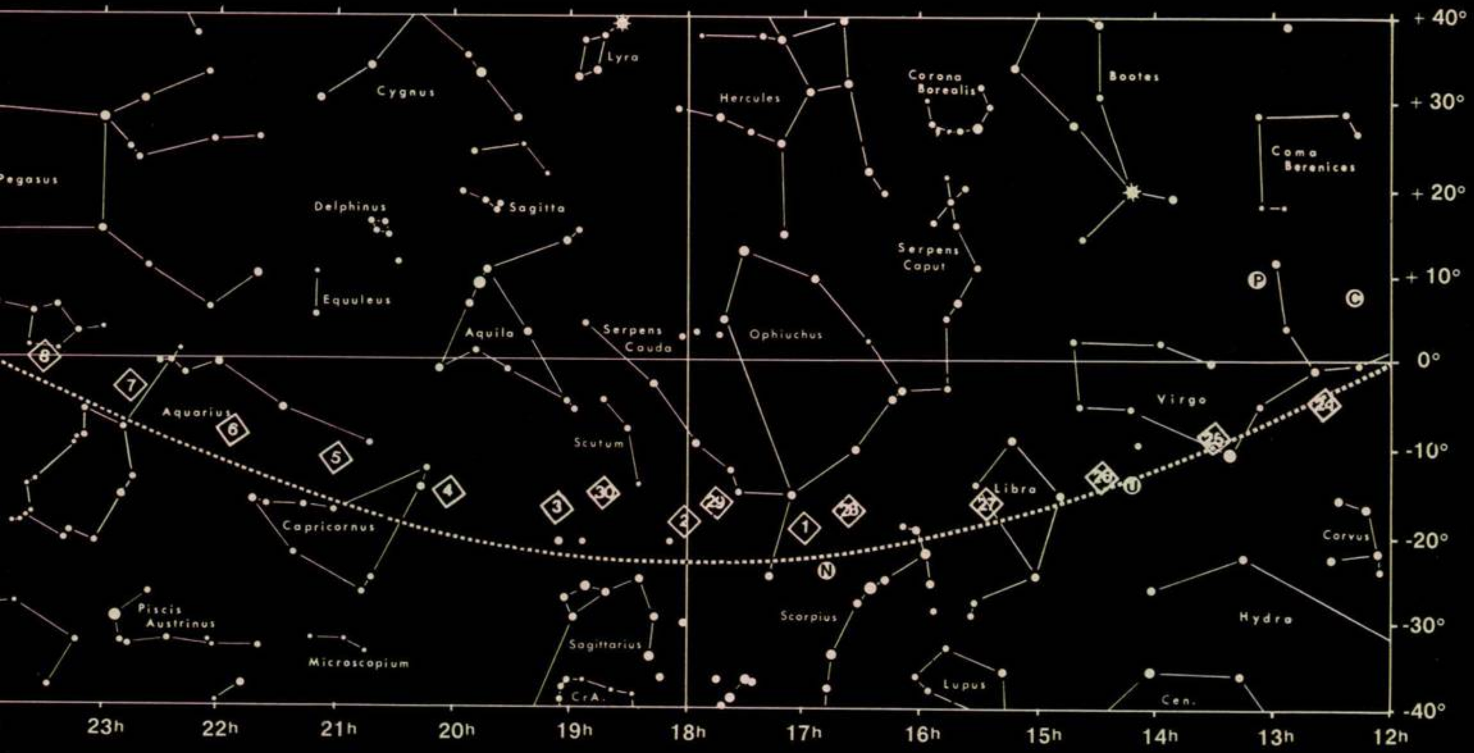
Full Moon

June 1
June 30

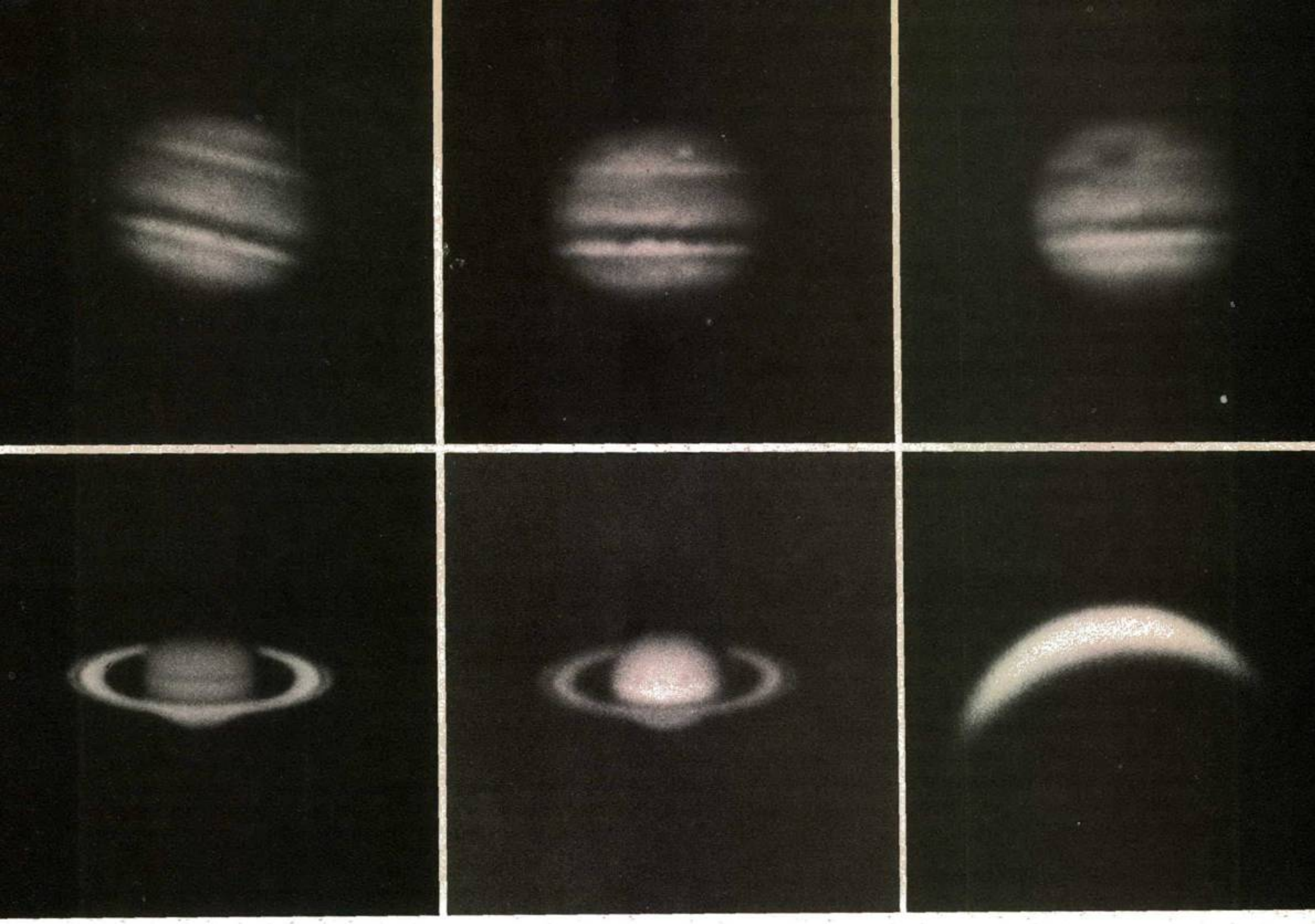


Last Quarter

June 8


Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Pegasus
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Capricornus
Corvus
Scorpius
Piscis Austrinus
Sagittarius
Hydra
Microscopium
Lupus
CrA.
Cen.
P
C
N
U
8
7
6
5
4
3
30
2
29
1
28
27
26
25
24
+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.



Opposite, top, left to right: These four photos — all 1/125 second exposures on Kodachrome 64, and all taken at the prime focus on a homemade six inch f/7 Newtonian — show the progress of the April 3 partial lunar eclipse. At left (10:25 p.m.), the moon will enter the umbra in five minutes. Next (10:40 p.m.), the moon is 10 minutes into the umbra. The third photo (11:00 p.m.) shows the moon a half hour into the umbra, and the photo at the far right (11:17 p.m.) was obtained one minute prior to mideclipse. Photographs by L.H. Price. Center: Shortly before mideclipse, infrared film and a Wratten #29 filter combined to produce the startling image of the lunar eclipse seen here. This is a 1/15 second exposure obtained with an eight inch f/10 reflector. A more conventional shot of the eclipse is shown at right — a 1/15 second exposure on Fujichrome 100 film (without filter). Photographs by George F. Hodgkinson. Bottom left: This photo was taken at the prime focus of a Cave eight inch f/7 reflector. Exposure time is 1/250 second; the film used was Kodak Ektachrome 200. Photograph by Terry Haave. Bottom right: The moon approaches maximum eclipse in this 1/60 second exposure on High Speed Ektachrome. The picture is one of the first taken through the photographer's newly obtained Dynamax 8. Photograph by David W. Dorsey Jr. Above: Several excellent photos of the planets obtained in recent months show fascinating detail. Top, left to right: Jupiter exhibits its changing face in pictures taken months apart (on Nov. 16, Dec. 15, and Feb. 1). Exposure times are 1/2 second, 1 second, and 2 seconds. A medium blue filter was used for the photo at left, and dark blue filters for the other two. Bottom, left and center: These two photos of Saturn were taken a month apart (Feb. 10 and March 10), The photo at left is a three second exposure through a medium blue filter, while the center photo was exposed for seven seconds through a light red filter under a "very hazy but steady sky". Bottom right: This photo of Venus is a 1/30 second exposure. All six of these pictures were taken on Tri-X film through the 12.5 inch f/16 Tinsley Cassegrain telescope at the Talcott Mountain Science Center at Avon, Conn. Photographs by Thomas Rotkiewicz.

During July, Mercury will slowly creep from behind the sun, heading for an August eastern elongation date. On July 13 and 14, it will move just north of M-44, the Beehive cluster in Cancer, and on July 19, it will be 0.4 degrees from Saturn, very low in the western sky. Again, use binoculars if you can't make them out with the unaided eye.

Venus

The brightest planet gleams at magnitude -3.9 during June, only slightly less bright than it was at greatest brilliancy in May. For about two hours before dawn, Venus is by far the most prominent object in the eastern sky — you can't miss it! It will be at greatest western elongation — its farthest distance from the sun (46 degrees) — on June 15.

Venus is in conjunction with Mars again on the morning of June 3, passing only 1.2 degrees south of the red planet. The pair's brightness and color contrasts will provide a stunning sight to early risers. Later in the month, on June 12, the waning crescent moon will pass just two degrees south of Venus. Since Mars will still be nearby, the three will be a very pretty sight.

In July, Venus continues to dominate the eastern sky, diminishing very slightly in brilliance. The crescent moon will again pass near it on July 12, and at the end of the month, Venus will be in conjunction with Jupiter.

Bright Asteroids at Opposition in June

Name	Opposition Date	Location at Opposition R.A.	Location at Opposition Dec.	Magnitude	Constellation
192 Nausikaa	June 6	16^h55^m	-33°59'	10.2	Scorpius
230 Athamantis	June 8	17^h00^m	-18°04'	10.6	Ophiuchus
39 Laetitia	June 16	17^h36^m	-07°49'	10.3	Ophiuchus
11 Parthenope	June 21	17^h58^m	-18°35'	9.4	Sagittarius
511 Davida	June 22	18^h00^m	-16°42'	11.4	Sagittarius
13 Egeria	June 25	18^h13^m	-43°27'	10.9	Corona Australis

Venus' phase will be half on June 15 (its elongation date), after which it will move into the waxing gibbous phase. Why, then, if Venus' phase is becoming greater, is the planet dimming down? The answer is that Venus is now moving away from Earth, and the apparent diameter of its disk is slowly shrinking — from 29 seconds of arc on June 1 to 16 seconds on July 31. The planet's distance from Earth increases during June from 55 million miles (88 million kilometers) to 76 million miles (12.3 million kilometers).

Mars

Still in the eastern sky, Mars is gradually becoming brighter and easier to see with each passing month. Its distance from Earth decreases during June from 179 million miles (287 million kilometers) to 169 million miles (271 million kilometers), while its magnitude stays fairly steady at +1.3.

At 6 a.m. on June 12, the crescent moon passes 0.1 degree south of Mars; observers in South America and West Africa will witness an occultation at this time. Look to the east just before sunrise on that morning, and you'll be able to see the moon, Mars and Venus quite close together in a striking configuration. Photographers should be sure to capture this event on film. The moon will be very near Mars again on the morning of July 11.

Jupiter

The largest planet reaches conjunction with the sun on June 4, and is too close to the sun to be easily visible all this month. It will reappear in the morning sky in July.

Saturn

Saturn's magnitude during June is +0.6; as it moves away from Earth, its distance from us increases from 893 million miles (1,435 million kilometers) to 926 million miles (1,489 million kilometers). It can be found fairly low in the west at sunset, setting about two hours later. The four day old moon is six degrees away from Saturn on June 20.

Uranus, Neptune, Pluto

In the constellation Libra, Uranus continues slow retrograde motion through the month of June. The waxing gibbous moon is one degree north of our second ringed planet at 7 p.m. EDT on June 26; for observers in extreme northeastern North America, the planet will be occulted.

Neptune is at opposition (its best position for observing) on June 5, located in southern Ophiuchus, about two degrees north of the star 24 Ophiuchi. At 9 p.m. EDT on June 21, Neptune can be found two degrees south of the full moon.

Pluto, located in Virgo, is stationary on June 28, resuming direct motion thereafter.

Asteroids

Among the minor planets reaching opposition this month, note especially 11 Parthenope. After reaching opposition on June 21, it will move westward, brushing north of the open cluster M-23 for a few nights on either side of June 26. Other fairly bright asteroids can be found by checking their positions in the table on this page.

Summer Solstice

Summer begins in the northern hemisphere at 8:14 a.m. EDT on June 21, when the sun reaches the summer solstice — that point in its apparent path around the sky when it is farthest north of the equator. Winter begins at this time for residents of Earth's southern hemisphere.

Lunar Eclipse Report

The partial lunar eclipse that took place on the evening of April 3 was widely observed over the entire United States. Reports and photographs on the eclipse poured into ASTRONOMY offices; several of the more interesting photos are reproduced on the preceding pages.

One of the more interesting reports came from Karl Simmons of Jacksonville, Fla., who wrote in part: "An interesting eclipse, with color! A very distinct copper-red was suddenly noticed at 11:07 p.m. EST in a 33 centimeter (13 inch) reflector. Color was certainly not expected to be very noticeable! The coloration covered perhaps 30 percent of the area in shadow at mideclipse and was strongest along the lunar limb. Color was not seen with 7 x 50 binoculars or naked eye. The coloration had begun to fade by 11:32 p.m. and no traces of it were seen by 11:46 p.m. . . . The umbra was very dark. Nothing could be seen in the area along the limb that was covered by the umbra."

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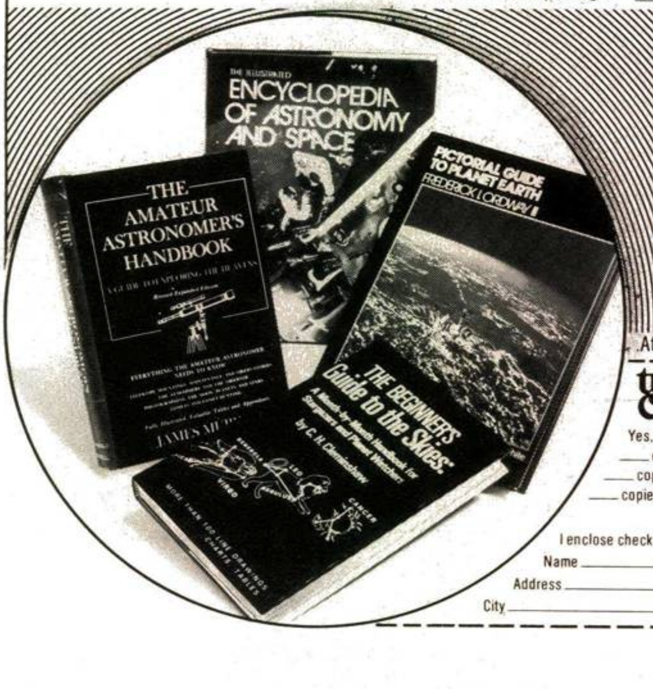
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A SECOND RINGED PLANET

by

Mary Jane Lamers

On March 13, 1791, the well-known English astronomer William Herschel was conducting one of his systematic scans of the night sky from his backyard in Bath, England. He wasn't looking for a planet, but that night he discovered Uranus. Almost 200 years later, in the early morning hours of March 10, 1977, what had begun as a measurement of the diameter of Uranus and readings of its atmosphere turned out to be another accidental discovery — and one of the more important in recent times!

On that morning, a rare occultation of a star by Uranus took place. Astronomers in four locations recorded the event, including: J. Elliot, E. Dunham and D. Mink aboard NASA's Kuiper Airborne Observatory, as it flew over the Indian Ocean; R. Millis, P. Birch and D. Trout at the Perth (Australia) Observatory; J. Churms at the Capetown Observatory, and J.C. Bhattacharyya and K. Kuppuswamy at the Kavalur (India) Observatory.

The star, SAO 158687, is a relatively dim one (magnitude 8.8); by comparison, Uranus is fairly bright, and the astronomers had to use sophisticated equipment. A highly sensitive photometer aboard Kuiper Observatory began to record fluctuations in the light of the star *prior* to the actual occultation. This signal that something unexpected was happening occurred about 40 minutes before the star was due to pass behind Uranus. Photometers recorded a dip in the light readings for seven seconds, and for the next nine minutes the light was cut off four more times for intervals of one second each.

Preliminary analysis of the data by Elliot on March 12 showed the possibility of about 100 satellites orbiting the planet. He said he had identified several satellites 18 to 24 miles (28 to 38km) in diameter. Millis said he had identified a satellite of about 60 miles (100km) in diameter.

Further study of the information has changed this picture somewhat. Elliot and his associates from Cornell now believe that five rings orbit Uranus — each orbiting above the planet's equator in a narrow belt 4,400 miles (7,000km) wide and lying 11,000 miles (18,000km) out from the surface of the planet's cloud cover. The five rings now appear to consist of four thin inner rings approximately 6 miles (10km) across, orbiting the planet in a circular manner, and a fifth ring whose orbit is not exactly circular, approximately 60 miles (100km) wide.

The rings have been named using the first five letters of the Greek alphabet. From the innermost to the outermost, they are called Alpha, Beta, Gamma, Delta and Epsilon. The ring system is extremely thin in proportion to the planet and its moons. The outermost portion of the rings is 11,000 miles (18,000km) from the planet. The orbits of Uranus' five known moons (Oberon, Titania, Umbriel, Ariel and Miranda) lie from about 350,000 miles (586,000km) to 76,000 miles (123,000km) from Uranus.

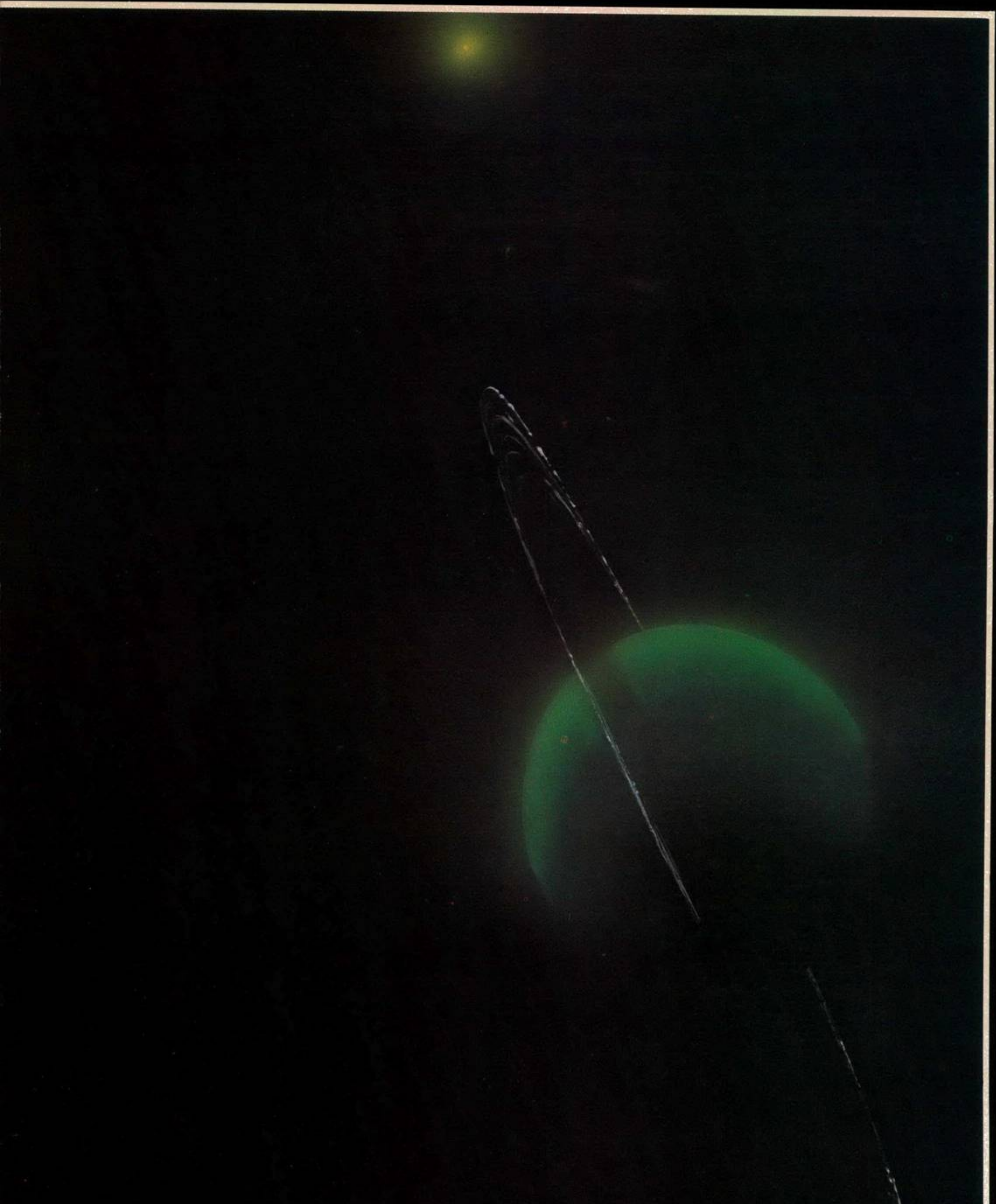
ASTRONOMY interviewed Brian Marsden of the Smithsonian Astrophysical Observatory about this amazing discovery. When asked if astronomers could be jumping to conclusions by inferring the presence of rings, Marsden replied, "We might be. There is certainly something out there. I think there are enough consistent observations to indicate that something out there is very unusual."

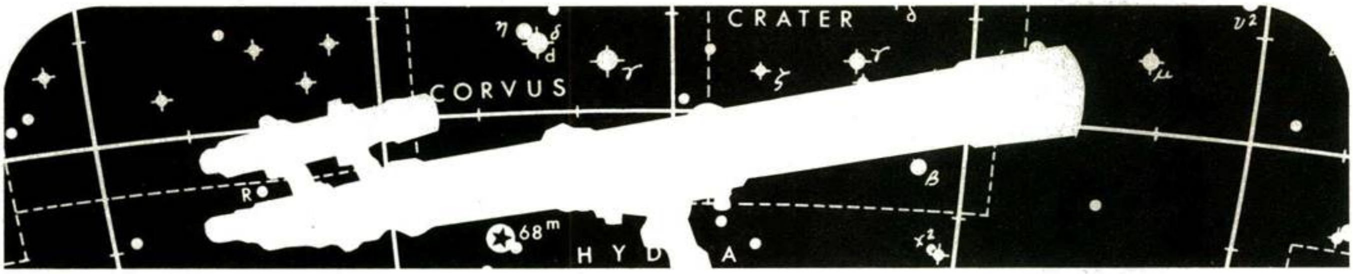
When asked about the composition of the rings, Marsden said, "The rings probably consist of rather small particles — dust or ice particles like Saturn's rings. They're distributed in a uniform manner, which is why every astronomer who observed them saw one and only one ring for each interval. I think all the indications are that we're dealing with dust."

The occultation itself was a relatively rare event. Marsden said the chances of witnessing an occultation by a slow moving planet like Uranus are not very great. He mentioned the possibility of an occultation of some dim stars by the ring area in late May.

None of the ground based observers were able to record the event in its entirety; changing weather conditions and the approaching dawn were cited as two of the major reasons. Because they were flying above 75 percent of the atmosphere, only the Cornell team on board the Kuiper Observatory recorded the entire event.

Uranus has been surprising astronomers for two centuries. In William Herschel's backyard, it was the first planet to be discovered through a telescope. Now 200 years later, its rings are another discovery of major importance to be made from a flying observatory. One can only guess what future surprises Uranus has in store. Perhaps future space probes will unravel some of the mystery.





EQUIPMENT ATLAS

Beginning With Your Telescope

by

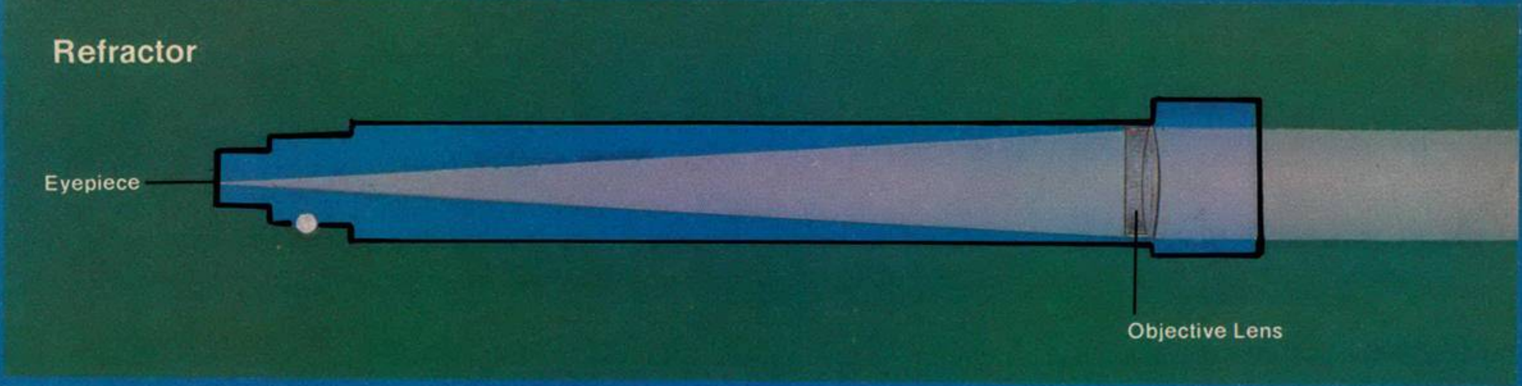
Mary Jane Lamers

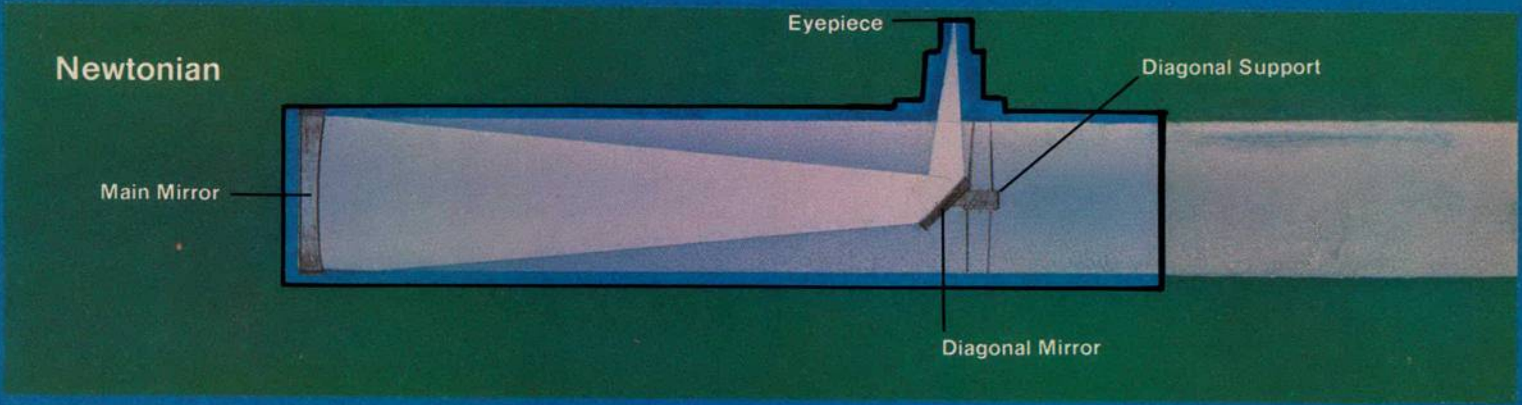
Astronomy enthusiasts are a diversified breed of people, running the gamut from the casual backyard stargazer with binoculars, to groups of observers who go on expeditions to any and all parts of the world with hundreds or thousands of dollars' worth of equipment. The hardest part in crossing that line between being an "armchair astronomer" and actually going out to do some observing is the commitment involved. This commitment usually entails buying (or receiving as a gift) a telescope for your very own.

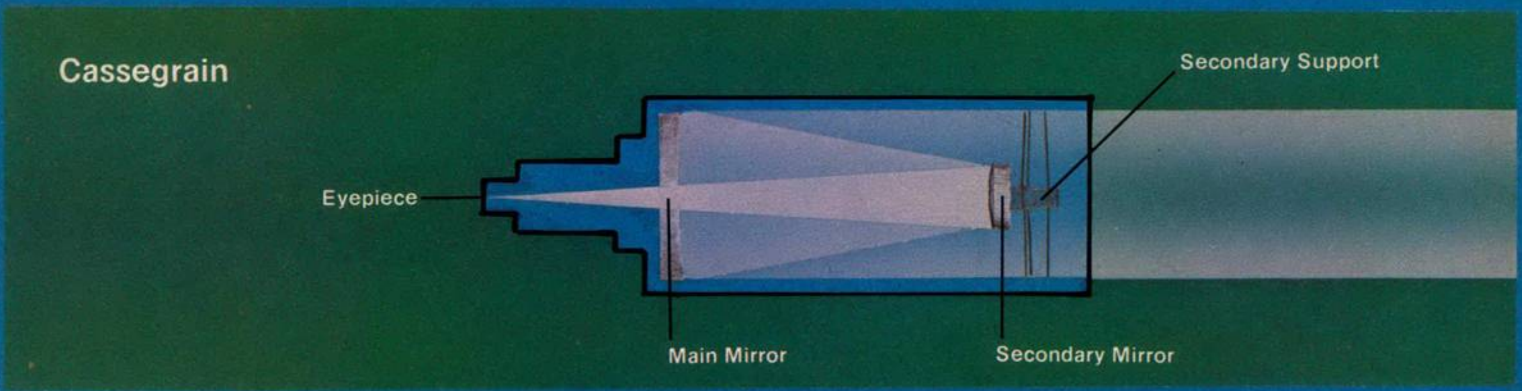
Let's assume you have a brand new telescope. Among many questions facing you, the primary one is probably, "How do I get it to work?" This article is intended to give you a basic introduction to the telescope and its workings; most of the descriptions will be very general — only what you need to know if you're just starting out. Before we begin, a word of caution: *Take your time* in attempting a project of this sort. It may take a while to get used to terms and concepts unfamiliar to you.

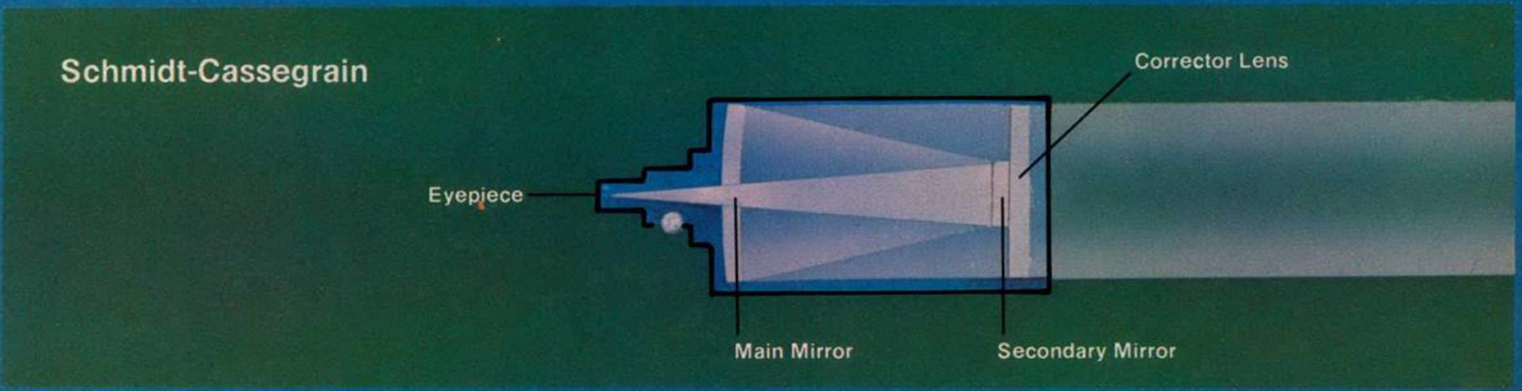
Before settling down to serious business, plan a night of observing just for the fun of it. Take your

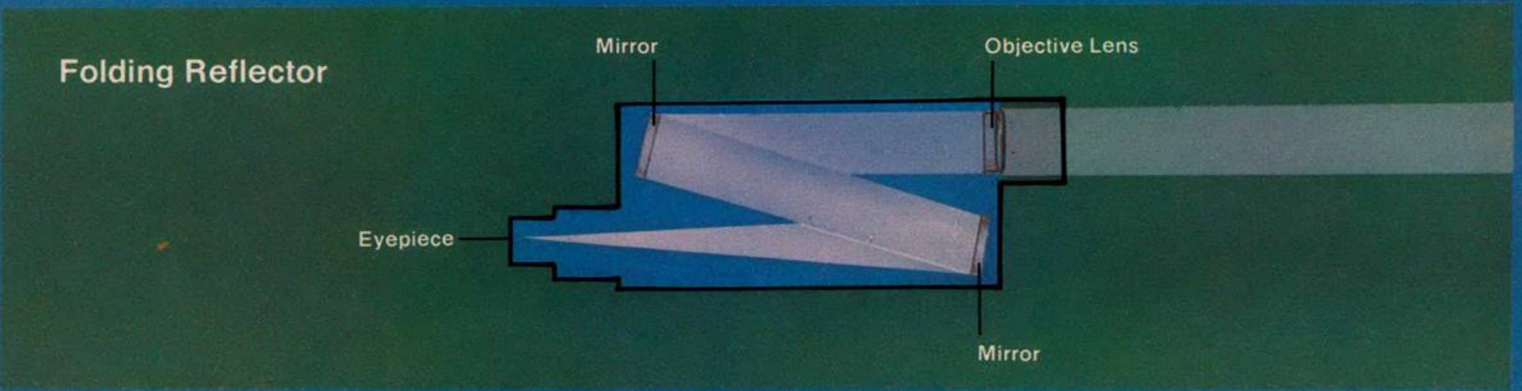
This diagram shows five examples of telescopes — two refractors and three reflectors. The Newtonian, Cassegrain and Schmidt-Cassegrain are examples of the reflector telescope. The remaining two are examples of refractors. Artwork by Mark Paternostro.

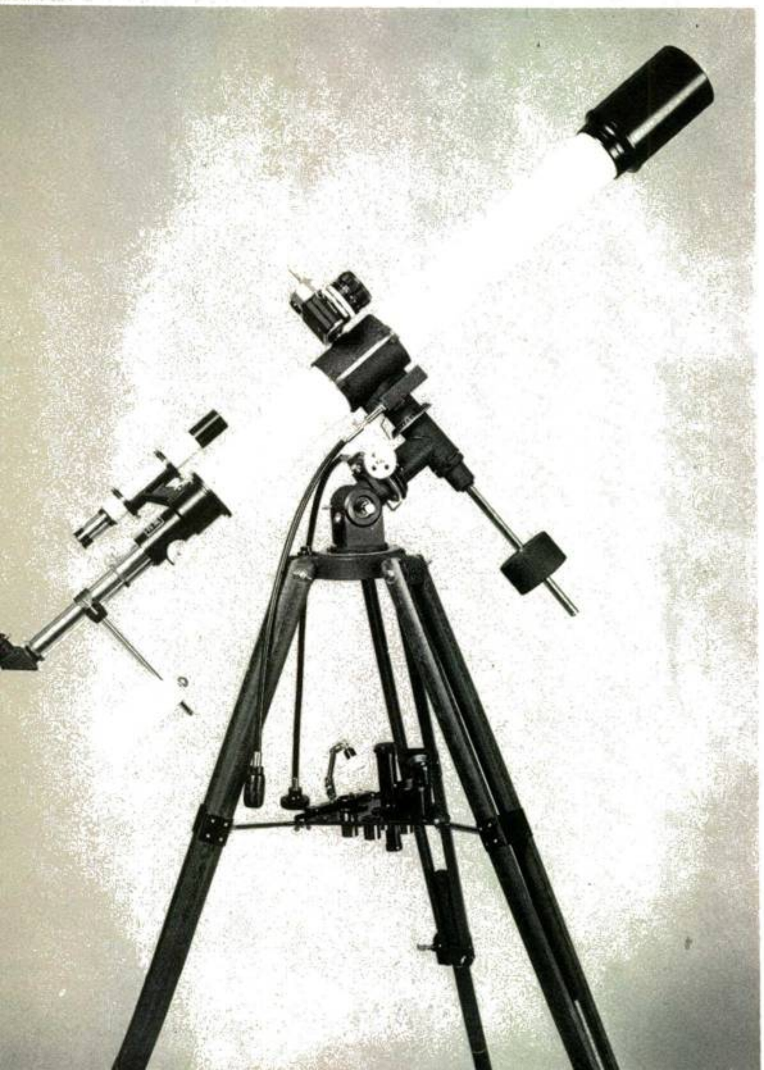

Refractor
Eyepiece
Objective Lens

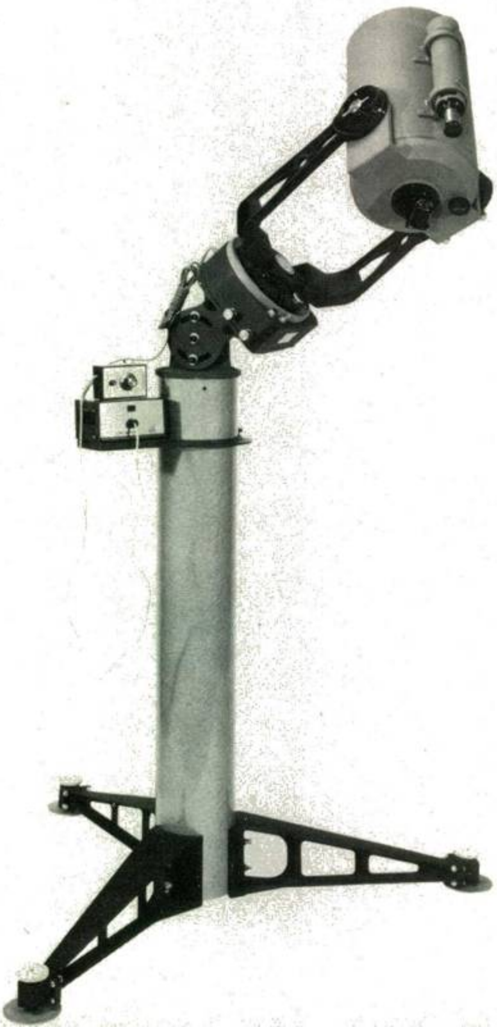

Newtonian
Eyepiece
Diagonal Support
Main Mirror
Diagonal Mirror

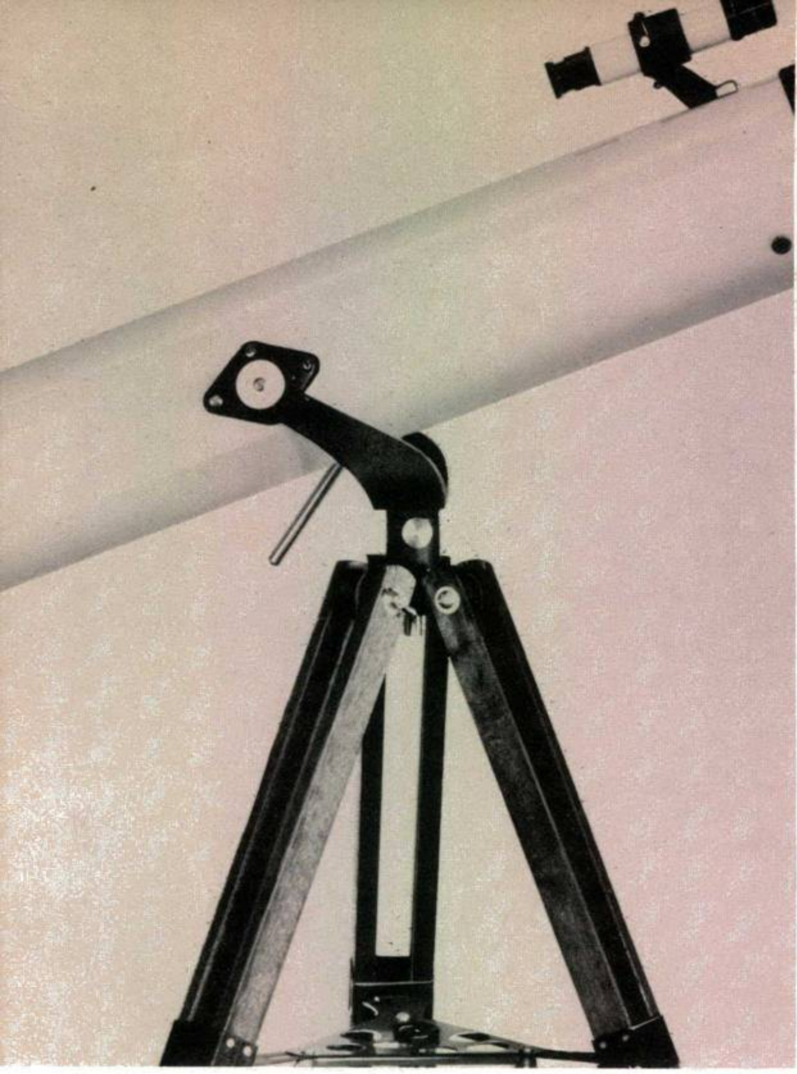

Cassegrain
Secondary Support
Eyepiece
Main Mirror
Secondary Mirror

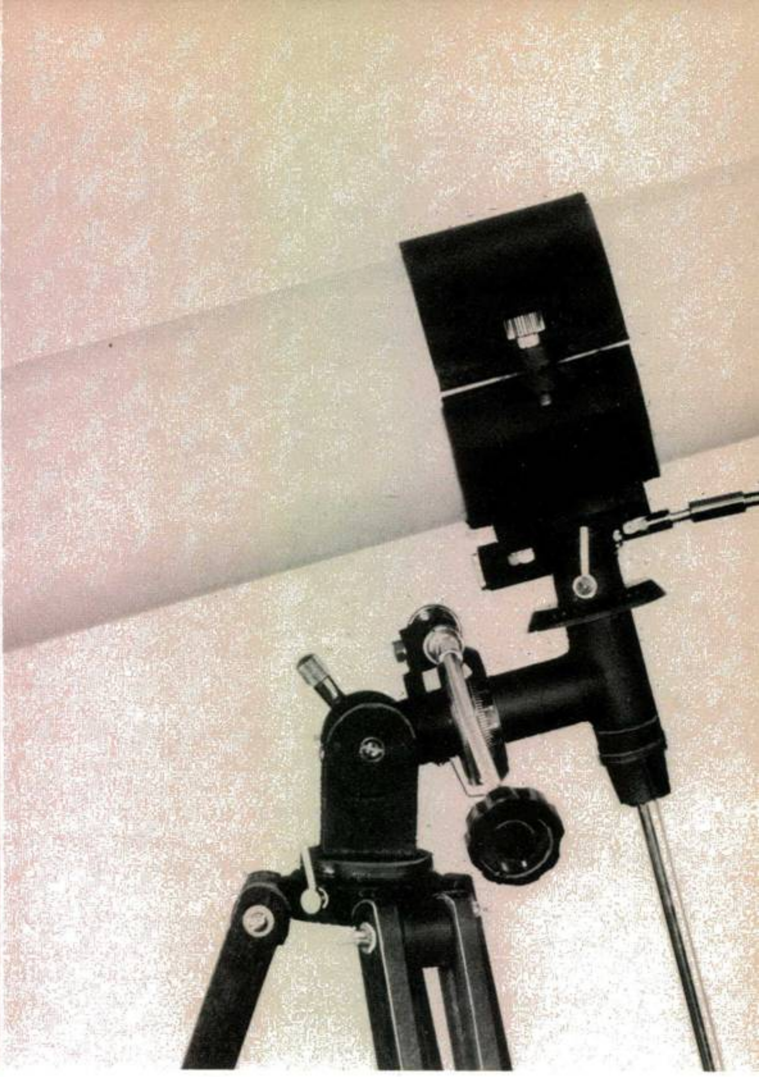

Schmidt-Cassegrain
Corrector Lens
Eyepiece
Main Mirror
Secondary Mirror


Folding Reflector
Mirror
Objective Lens
Eyepiece
Mirror









Opposite: Shown here are the most commonly used types of telescopes and telescope mounts for the beginner. Top left: This compact eight inch Schmidt-Cassegrain on its fork equatorial mount has the advantage of not needing heavy counterweights. Top right: The eyepiece located in the upper portion of the tube is a giveaway that this is an eight inch Newtonian on a German equatorial mount. Lower left: This is a 3.1 inch refractor; its characteristically long tube is set on an equatorial mount complete with accessories. Lower right: An eight inch Schmidt-Cassegrain is shown again, this time on a pier mount with an additional attachment for holding the drive corrector. Above: There are only two types of telescope mounts — the altazimuth and the equatorial. The altazimuth (left) employs up-and-down and side-to-side motions. The equatorial (right) employs circular motions and, when set properly, can trace an object's path as it crosses the night sky.

telescope out to your backyard or wherever is convenient, and play with it for a while. If you want to look at a bright star, point the telescope at it and see if you can find it. The moon is a great subject for this sort of hunt-and-peck; you can hardly miss it. After a while it may get a little frustrating trying to find a binary — or even *one* star! At this point, you may decide it would be a lot easier if you knew how to use your telescope correctly. It may take you a while to learn the principles involved, but in the long run you'll find it's worth the effort.

Reflectors and Refractors

There are two basic types of telescopes: *reflectors and refractors*. The words are similar, so don't feel bad if you get them mixed up from time to time — you can always look them up.

The *refractor* is the simpler of the two. It consists of a long tube with a piece of glass situated inside it near the top. This glass is called the *objective lens*. It bends the incoming light rays to meet at a focal point at the lower end of the tube. Insert your eyepiece to enlarge this *primary image*, and you're all set (see the diagram on page 29).

The *reflector* is a bit more complicated. The telescope is shorter and wider, and the light bounces around a bit instead of traveling in a straight line. The tube is open at the top and has a curved concave mirror (the *main mirror*) at the bottom. The light coming in hits the main mirror and is reflected upward to the *diagonal mirror* located inside the upper portion of the tube. The diagonal mirror usually reflects the image out the side of the tube to the eyepiece. This is the point where the light rays come to a focus. As with the refractor, the eyepiece magnifies this image for the observer.

Doesn't the diagonal mirror cut off a lot of light? It does and it doesn't. A portion of the incoming light rays are blocked off, but there is still a more than sufficient amount (usually about 90 percent) that reaches the main mirror.

Among the better known types of reflectors

EQUIPMENT ATLAS *continued on page 34*

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are the Newtonian and Cassegrain. Other types of telescopes include both lenses and mirrors, such as the folded refractor and the Schmidt-Cassegrain. (See the diagram on page 29 for their differences.)

The Telescope Mount

As with the two main types of telescopes, there are two types of telescope mounts: the *altazimuth* and the *equatorial* mounts.

The *altazimuth* mount is the easiest to handle. It has two very simple motions: up and down or *altitude* motion, and side-to-side or *azimuth* motion. (Combine the two words and you have altazimuth.) The altazimuth mount holds the telescope in a yoke which can best be compared to a horseshoe configuration. The tube moves up and down in this yoke — the altitude movement. The side-to-side motion is accomplished with the use of a horizon pivot (it's almost like a gatling gun!). The telescope may also be fitted with slow motion mechanisms, so you can accomplish either motion without touching the tube. The actual tracking may be somewhat difficult with an altazimuth mount as opposed to an equatorial, because tracking with the altazimuth requires using both slow motion controls simultaneously, while the equatorial requires only one.

The *equatorial* mount may be a bit more complex, but it's far superior to the altazimuth when you want to observe a specific object for an extended period of time. As you become more skilled in observing, you'll find it's a requirement for long guided exposures in astrophotography. The main difference from the altazimuth mount is that the azimuth axis is tilted to point at the north celestial pole (see the diagram on page 36). Before you panic at these names, think of the pictures of star trails you've seen — lots of lines in a concentric pattern, with everything rotating around a central point near Polaris, the pole star. Earth rotates on its axis, and stars pass across the sky much like the sun does every day. The sun seems to travel from east to west, but actually it's Earth rotating past it in a west to east motion. The same is true of stars — they don't rotate; they are stable while we rotate past them. This is why tilting the "pole star axis" is so important. When the telescope's polar axis is properly aligned with the north celestial pole, it will follow the path of the star or object as it "crosses" the sky. So, if you want to follow a star, you need only turn one knob — the one that rotates the polar axis — to keep it in the field of vision. A little motor that turns the knob for you is called a *clock drive.* (One thing to keep in mind is that your telescope's polar axis must be adjusted to your latitude — a point that will be discussed later.) The other motion — the declination axis — works like an "altitude" adjustment. Once you're on a star, you won't have to adjust it again.

Right Ascension and Declination

Right ascension and *declination* coordinates provide the information needed in order to find the position of a particular object. Before delving into specifics, you should understand the concept of the celestial sphere as a whole to see how these coordinates function.

Imagine that Earth is enclosed inside a hollow transparent ball — an imaginary ball called the celestial sphere. In this sphere, Earth's poles and equator are extended outward and are appropriately named the *celestial poles* and the *celestial equator.*

Positions of objects in the sky can be determined in much the same way that locations of places on Earth are determined — by using latitude and longitude. Latitude is given in horizontal divisions that begin with zero at the equator and increase north or south in degree units. Longitude is given in vertical divisions beginning with zero degrees at the Greenwich Meridian and increasing westerly in units of 15 degrees to 180 degrees. The same amount (180 degrees) is calibrated east until the two half circles meet at the International Date Line.

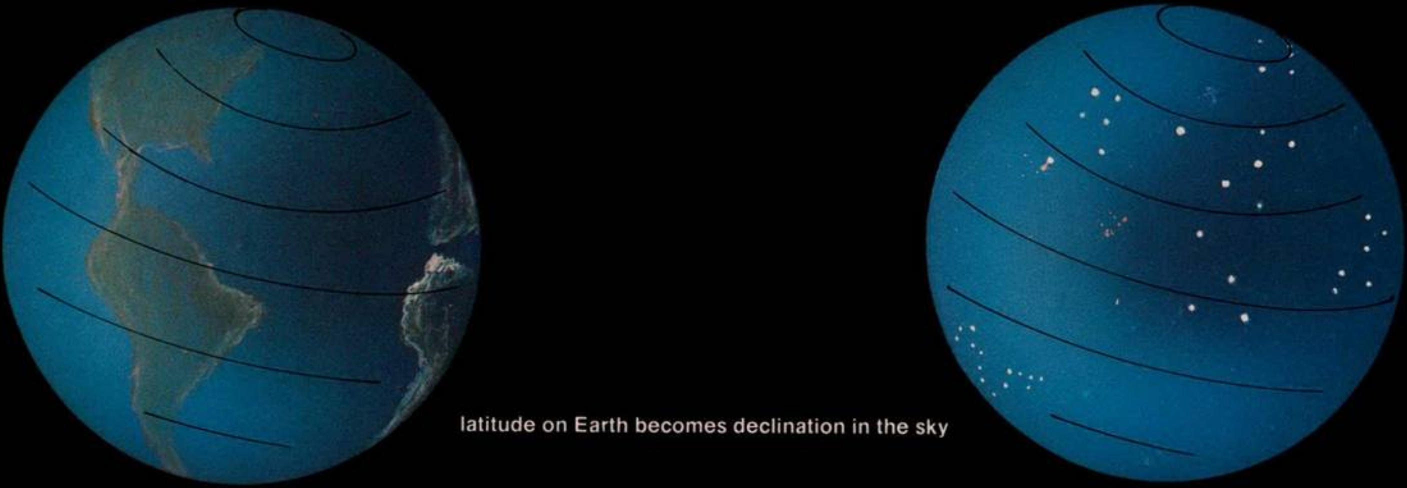
Right ascension and declination are the longitude and latitude of the sky. On the celestial sphere, right ascension can be compared to longitude on Earth. The celestial sphere is divided into 24 *hour circles* (actually half circles), counting east from the sky's "Greenwich Meridian". On the celestial sphere, this prime meridian is designated as the *vernal equinox* or the First Point of Aries — the point where the sun crosses the equator northward, and spring begins in the northern hemisphere. Actually the title "First Point of Aries" is a misnomer. Instead of lying in the constellation Aries, precession has shifted the point so that it today appears in Pisces (see the diagram on page 35).

Declination on the celestial sphere can be compared to latitude on Earth. Just as Earth latitude extends from 0 to 90 degrees north and south of the equator, declination extends from 0 to 90 degrees north and south of the celestial equator. The 90 degree north and south designations on Earth are known as the north and south poles — so it follows that on the celestial sphere the 90 degree north and south designations are known as the north and south celestial poles. Declination references are usually given in degrees; for greater accuracy minutes and seconds (subdivisions of degrees) are also used.

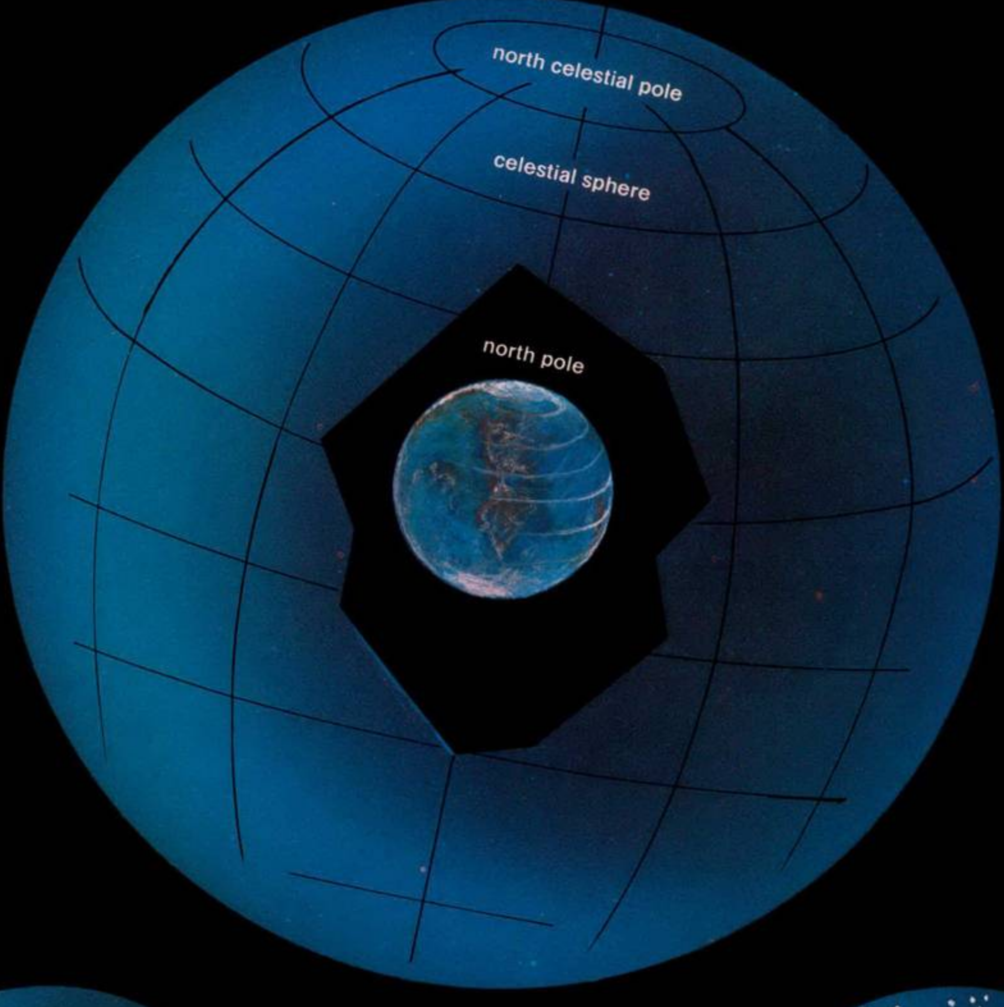
Checking It Out

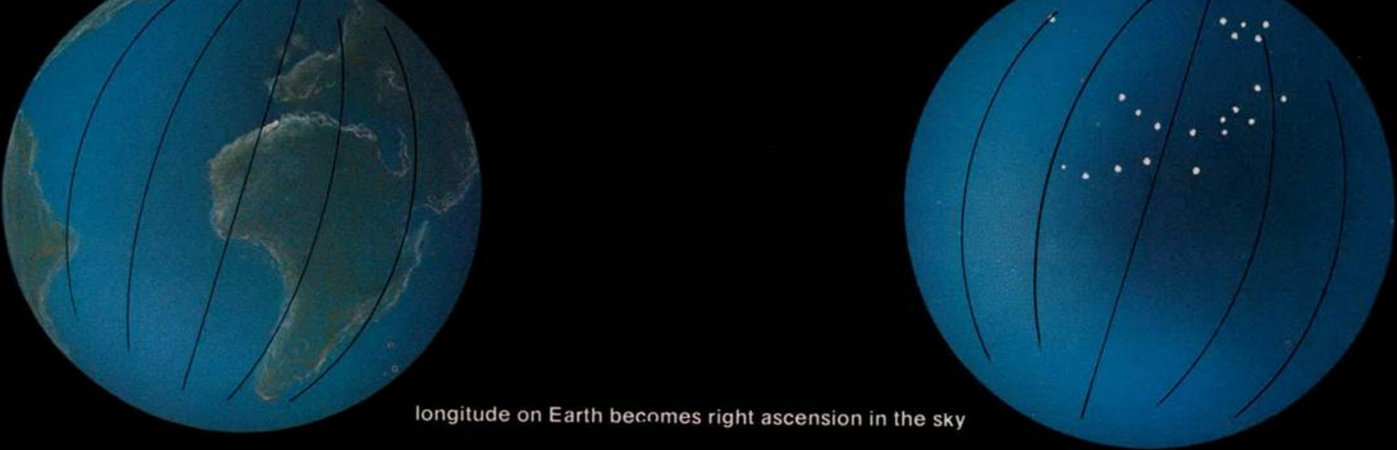
Before taking your telescope out for an evening, you should examine it to be sure it's in perfect working order. It should be balanced, the optics clean and free of dust, and the finderscope aligned.

The diagram at center illustrates the concept of the celestial sphere. The smaller spheres compare the sky's coordinates — right ascension and declination — to Earth's longitude and latitude. See text for details. Artwork by Mark Paternostro.

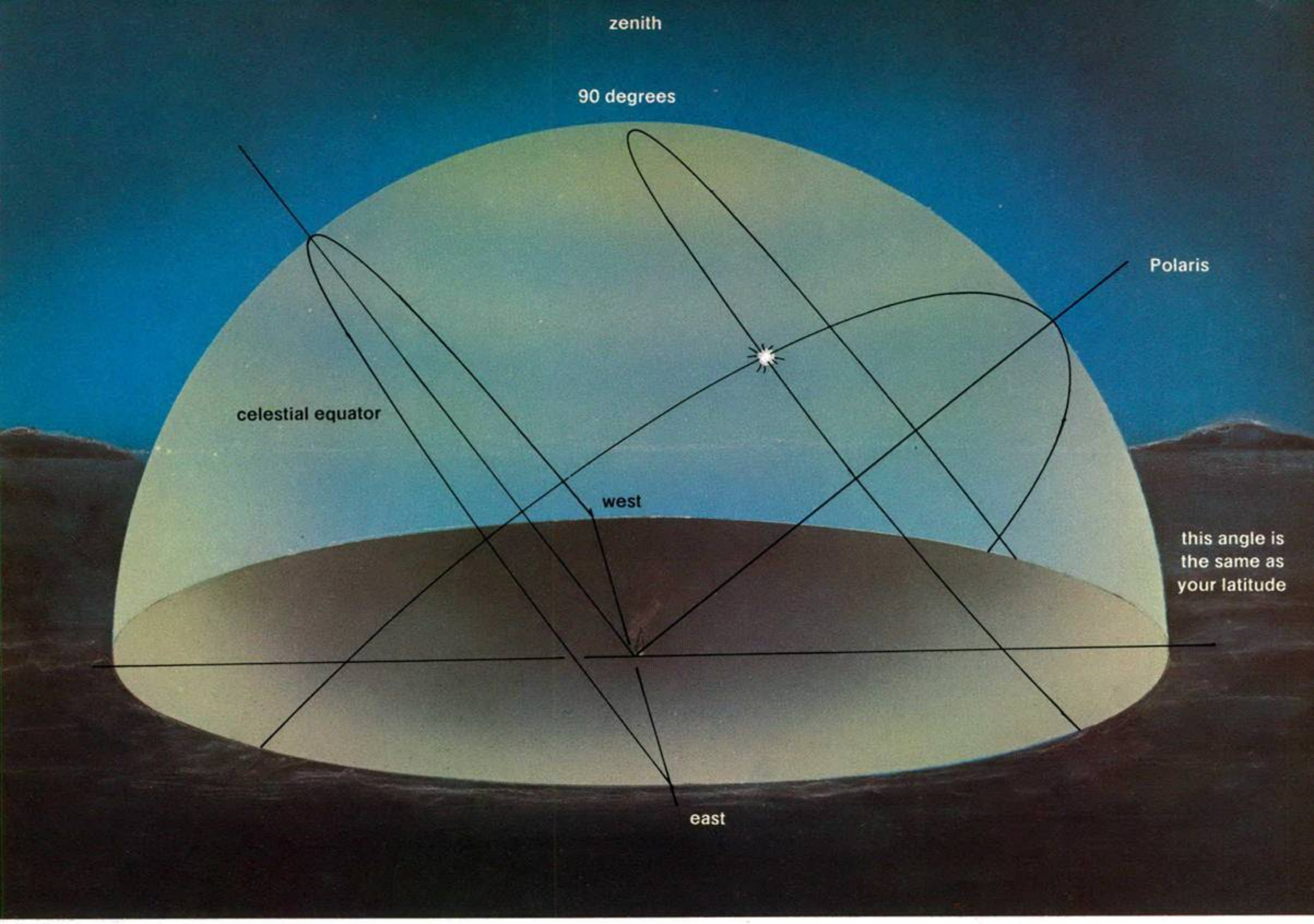


latitude on Earth becomes declination in the sky


north celestial pole
celestial sphere
north pole



longitude on Earth becomes right ascension in the sky



Many geometrics are involved in setting up your own telescope. The angle formed from Polaris to ground level is the same as your latitude. There is also a 90 degree angle between Polaris to the celestial equator. Artwork by Mark Paternostro.

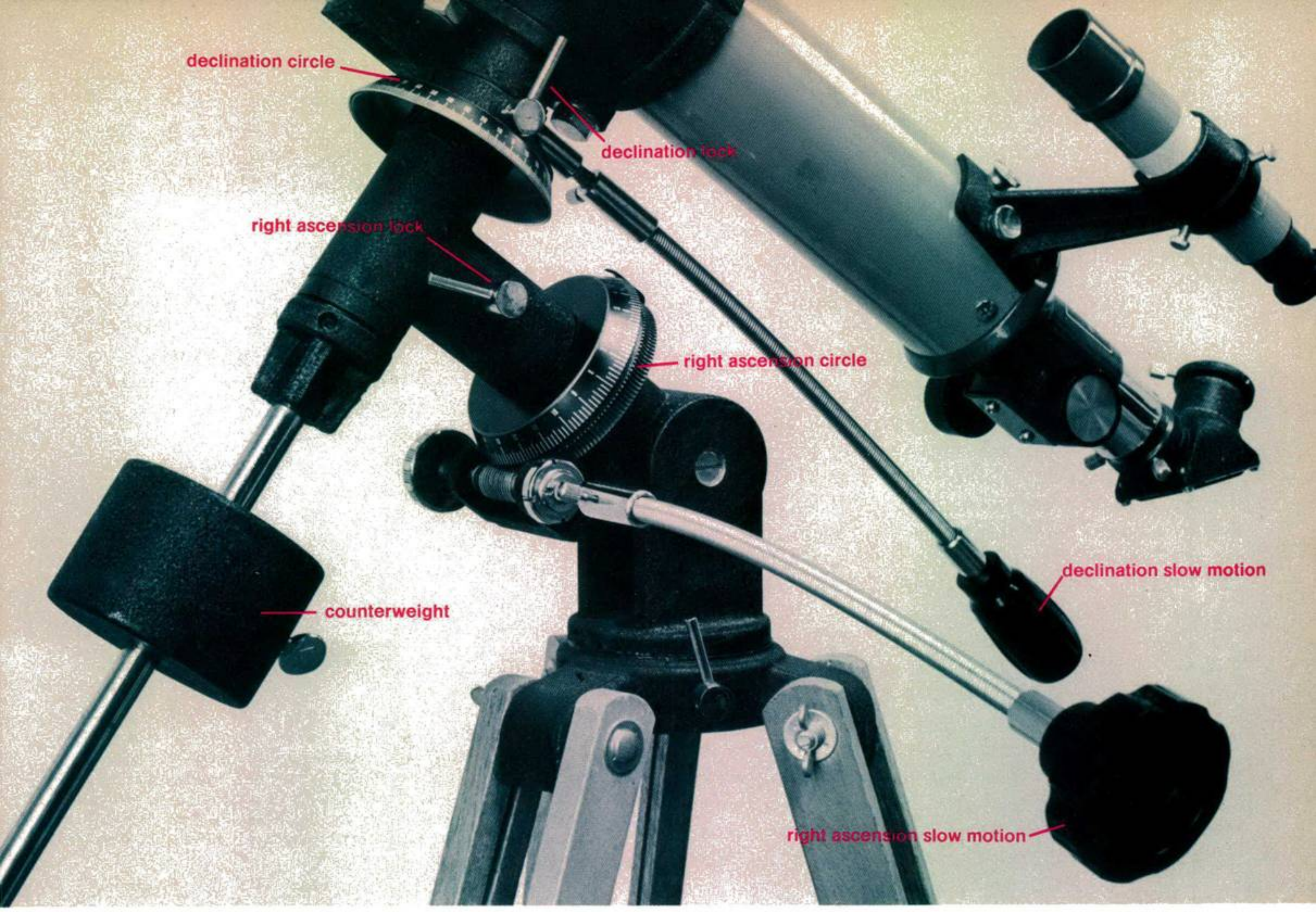
Additionally, make sure your right ascension and declination locks are in proper working order. Doing these things beforehand will increase your familiarity with the telescope and save some fumbling around in the dark when you finally do get outside with it.

The accuracy of your right ascension and declination locks is important because of the exact positioning required in order to find your way about the night sky. Once you find an object, you'll want to look at it for a little while, so you should be sure you can lock your telescope in position for observing. Without good locks you won't have the accuracy you need. The right ascension lock is the one on the polar axis (the part that points toward Polaris). The declination lock is located on the declination axis (the one with the counterweight on the end of it). Try both locks to see if they are working properly; they actually require very little maintenance. Should you find that one isn't working, have a mechanically inclined friend check it out — or get in contact with the telescope manufacturer.

Clean optics are an essential part of achieving satisfactory performance from your telescope. Preventive measures are the key here: Always use lens caps for your telescope and eyepieces. If you lose them, improvise with something like a shower cap or check to see if your local camera store can help.

An eyepiece usually doesn't require too much cleaning unless you've accidentally smeared a greasy thumbprint on to it. It's best to try to blow as much dirt off as you can. Then, take a damp soft cloth and gently rub off the remaining dust with light strokes.

Eyepieces are fairly simple to clean, but cleaning your telescope mirror is a whole different matter. Before you attempt to clean it, make sure you're justified in doing so (don't worry about a few specks). Too many washings can damage the coating on the mirror. As with the eyepieces, try to blow as much dirt off as possible. (You may want to purchase a can of compressed air; it's available in camera stores because it's mainly used for cleaning lenses — but would come in handy here.) The next step involves one of those wide camel hair brushes to remove the dirt, using light strokes. Be careful that you don't drag specks of dirt across the mirror, leaving a permanent scratch. If you feel the mirror is still too dirty you can wash it. Pour a cup of warm soapy water over it and wait a few minutes for it to soak in. Take a small wad of cotton (preferably wet) and wipe it over the mirror with light circular



This photograph shows the working parts of the equatorial telescope. The declination circle (which isn't movable) shows measurements in degrees, while the right ascension circle (which is movable) shows measurements in hours.

strokes. Rinse it off with tap water followed by two rinsings with distilled water. Prop the mirror up on a counter and you're all set. (For more information, see "Cleaning Your Telescope Mirror", ASTRONOMY, December 1976.)

The finderscope is an important part of the telescope that is often overlooked or disregarded. A few bad experiences tend to make the beginner think, "Why bother?" It really is a useful little tool and only needs minor adjustments now and then to keep it aligned.

Alignment is a must to avoid the "disease" known as "telescope frustration". The frustration attacks when you're all set for a night of observing and you find you have the thing out of whack. You may have the Orion nebula in your finderscope but the main scope shows a "black hole"! That's why it's a good idea to check your finderscope's alignment *before* you take the scope outdoors. Also, it's easier to check the alignment on your finder during the day when you have lots of light available. You can do this indoors or outdoors — the location really doesn't matter.

The first thing you do is sight the main scope on a distant object — a telephone pole is a pretty good choice. Line up the pole so that it is dead center in the field of vision. Now, being very careful not to bump anything, set the right ascension and declination locks. Look into the finder; the telephone pole should be in the exact center of the *reticule* or *crosshairs*. If it isn't, you should very gently loosen the screws that are on the mounting rings, moving them about until the pole is centered in the field. Then make sure the pole is still dead center in the main scope and you're all set. If it's night when you discover the finder is out of whack, find a bright star or the moon in the main telescope, and then align the finder on it.

It may look simple, but balancing a telescope is not that easy a procedure. Look at the weight distribution of the tube. In a refractor, the finderscope and eyepiece apparatus make the tube bottom heavy. The cradle should be clamped approximately 2/3 of the way down the tube so the lower third, which is heavier, can balance out the upper two thirds. You can move the body of the telescope tube by releasing the screw-clamp apparatus on the cradle portion. In a reflector, the mirror balances the eyepiece holder and finder. With most reflectors, you'll find the balance point is near the middle of the tube.

When you release the locks on the scope, it should remain in that exact position if it is balanced. If it always points one end to the ground, it isn't balanced. But you can balance it in a jiffy. First unclamp the declination axis and slide the tube back and forth until neither end plunges toward Earth. Then clamp the declination and unclamp the polar axis. If it doesn't stay put, move the counterweight up or down the shaft. After that, it should stay wherever you point it without clamping either axis. Of course, when you observe, you'll clamp it so that wind and little touches don't send it flying.

Setting Circles

Some people have no trouble at all with setting circles. They line up their telescope on the north celestial pole (see polar alignment below), turn it and instantly find something that the most you know about is that it begins with an "M". So now you want to do the same thing. But you should be aware of the time and practice which went into that impressive display. It *will* take a while, so don't get discouraged if your first attempts fail.

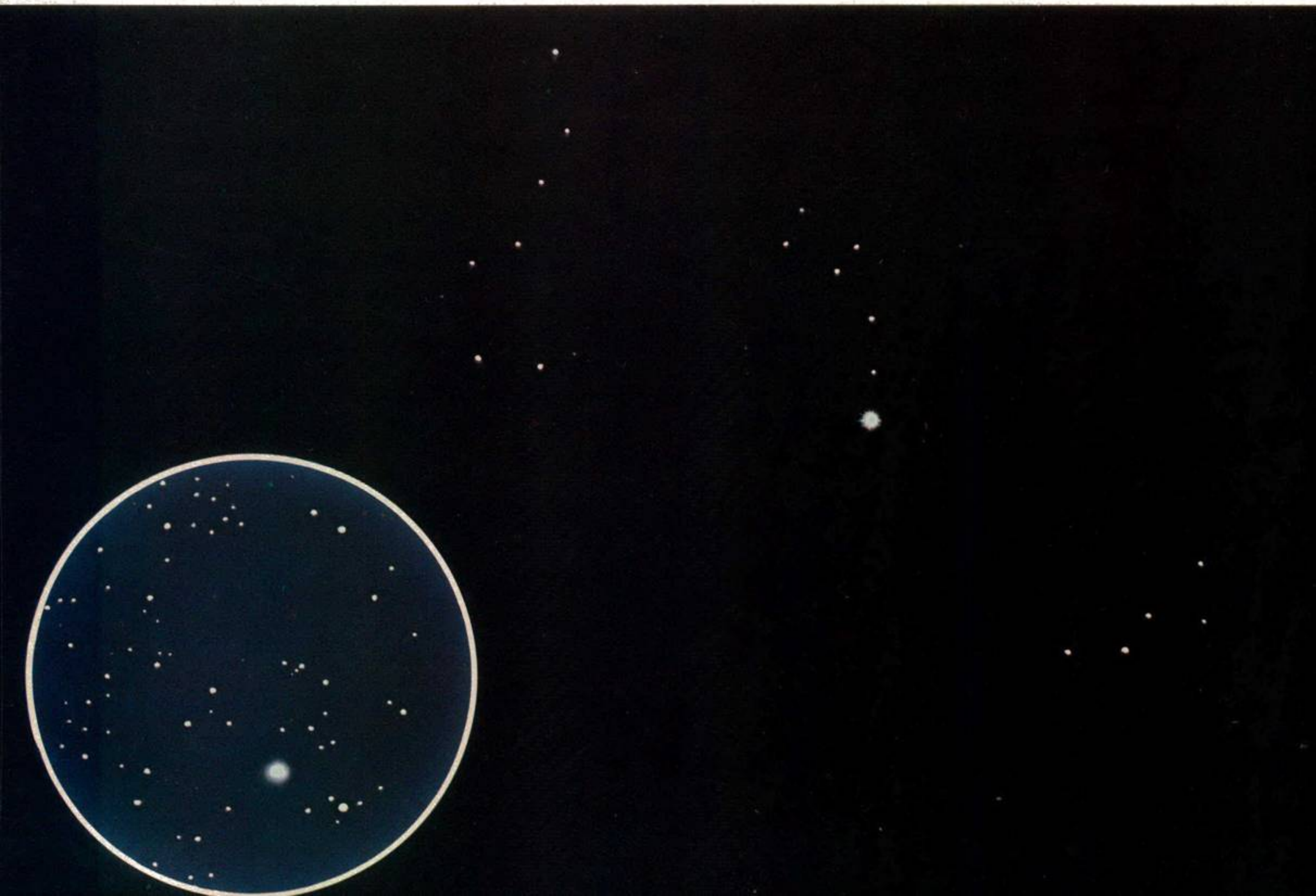
Very few observers rely on setting circles alone to find their way around the night sky. You *must* have a working knowledge of the constellations if you're ever going to get anywhere. H.A. Rey's book, **The Stars**, would nicely suit your purpose. The diagrams and associated illustrations make the strange shapes of the constellations easier to remember. Additionally, ASTRONOMY's Star Dome, Sky Almanac and Planet Finder sections may also be a help in locating specific planets or constellations.

It's important that you understand the concepts of right ascension and declination; if you have any doubts, go back and reread the section about them before you continue.

Because Earth rotates, objects appear to rise in the east and set in the west. At a given latitude, this rotation affects right ascension only; declination does not change. If you live at +40 degrees latitude, the sky declination of +40 degrees will *always* be overhead. This is why the declination circle (the one with the weight on the end of it) is so simple to use. Once your telescope is aligned with the north pole, the declination should read 90 degrees. If you dial zero degrees you'll be pointing toward the equator. At no time should you try to move the declination dial back and forth. The dial is set — unlike the right ascension dial which is movable.

Now comes the hard part: Earth's rotation keeps changing the right ascension. This is why the right

The exact location of Polaris is shown in this diagram. The easiest way to find Polaris is to draw an imaginary line from the end stars of the Big Dipper. These are the lower and upper stars in the outer part of the bowl portion. Just follow this line to the first bright star you see: Polaris. For those interested in doing precise work, the inset provides a detailed map, showing the exact location of the north celestial pole. Artwork by Mark Paternostro.



ascension circle is movable. Before you can use it, you'll need to use a star you're familiar with as a base from which to begin. For example, suppose you're looking for the open cluster M-35. The nearest star that you are familiar with is Castor, in the constellation Gemini. Roughly line the telescope up with Castor and center it. The right ascension of Castor is 7 hours 32 minutes; its declination is 31.9 degrees. Since you've already lined it up roughly, the declination circle (the one that can't be moved) should read about 31 degrees. (If the numbers on the circle are small as they are on many telescopes, you may only be able to guess at "about 32 degrees".) Next, move the right ascension circle so it reads 7 hours 32 minutes. Your setting circles are now in synchronized orientation (which means you've got the thing lined up right). In order to find M-35, move the tube until right ascension reads 6 hours 7 minutes, and declination reads about 24 degrees. With a little practice it becomes very easy to use.

Latitude Adjustment

An accurate latitude adjustment is an absolute necessity if you plan to do more than just play with your telescope. You can do this adjustment in your backyard provided you have a clean view of Polaris.

The first thing to do is to set your scope on a firm surface like concrete, asphalt or dry hard ground. Next, adjust the head of the scope (the part where the tripod legs meet) so it's level. A "bullseye" level is usually available at hardware stores. A carpenter's level will work too.

Loosen the bolt that locks the polar axis (it's always the large one that is located just above the tripod head). Don't loosen it too much, or the scope will do a nose dive.

Make sure the scope is pointing toward Polaris and is parallel to the polar axis (the one with the circle that has 0 to 24 marked on it). Set the declination circle to read 90 degrees. There are two 90 degree readings; use the one that points upward. Lock all the mechanisms except for the one that locks the polar axis.

Move the telescope until Polaris is in the center of the field of vision (don't forget your finderscope — it's handy here). If you jostle the tripod, just relevel the head again. With Polaris at dead center, lock the polar axis tight. Then check everything again; make sure it's level, the declination is set at 90 degrees, and Polaris is in the center of the field. You're all set. You'll never have to make this adjustment again unless you change latitude.

Polar Alignment

After making the latitude adjustment, the process of aligning your scope with Polaris will be easy. Aim the polar axis at Polaris and set your declination reading at 90 degrees. Now play with the tripod legs, adjusting them until you get Polaris centered in the finderscope. Unless you plan to do guided astrophotography (where you need precise centering), it is sufficient to center Polaris approximately in the center of the field. The reason for aligning your polar axis with Polaris is that you can then compensate for Earth's movement by turning one knob on the polar axis.

Rough alignment is sufficient for most visual observing, but if you want to use setting circles or do guided astrophotography, a more precise alignment is necessary. The following explanation is very general; a more detailed polar alignment article will appear in Photography in Astronomy in the near future.

Polaris is less than one degree from the north celestial pole, so precise alignment requires using the declination scale. Set the declination for 90 degrees and lock all the motions. Fidget with the tripod footing until your lowest power eyepiece is centered on Polaris. (The higher the number of millimeters on the eyepiece, the less powerful it is.) Select an eyepiece of 25mm. With most small telescopes this should give you a field of about one degree — twice the apparent diameter of the moon. Check the map on page 38, and center the north celestial pole in the middle of the field by adjusting the tripod. You should have a perfectly aligned telescope. If you run into problems, try going over the entire procedure again. If the same problems persist, have your telescope's declination dial checked to be sure it is accurate. Patience is a requirement with telescope adjustments!

The Real Thing

Finally, after going through all the trouble of finding out what makes a telescope "tick", you're ready to go out there. Where you want to do your observing depends on your personal preference. A general rule of thumb is: the darker the area, the better your dark adapted vision. Usually a half hour in a dark area is enough time.

It's a good idea to bring along some star charts, such as those that appear monthly in Star Dome. A good star atlas is better if you want a more comprehensive list. To help you find your way in the dark, use a flashlight covered with some red cellophane. (Red light won't ruin your dark adaptation as much as white light.) You'll have to choose your preference here — too much cellophane and you can't see to read the charts; too little cellophane and you lose out on your night vision.

Don't expect wonders on your first evening out. Take your time; there are lots of things to familiarize yourself with. If you tackle it all at once, you may just end up frustrated. As your knowledge of the night sky increases, it'll all fall into place. You'll have time to find detail that you never noticed before in addition to seeing many objects for the first time.

Good luck!

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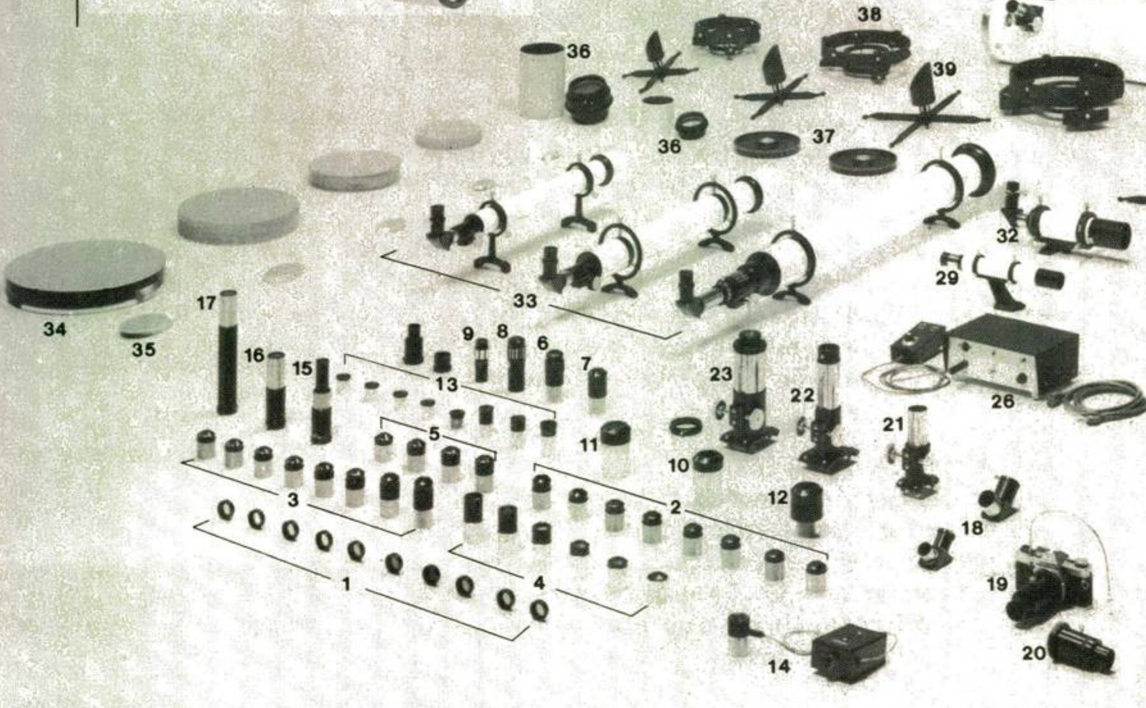

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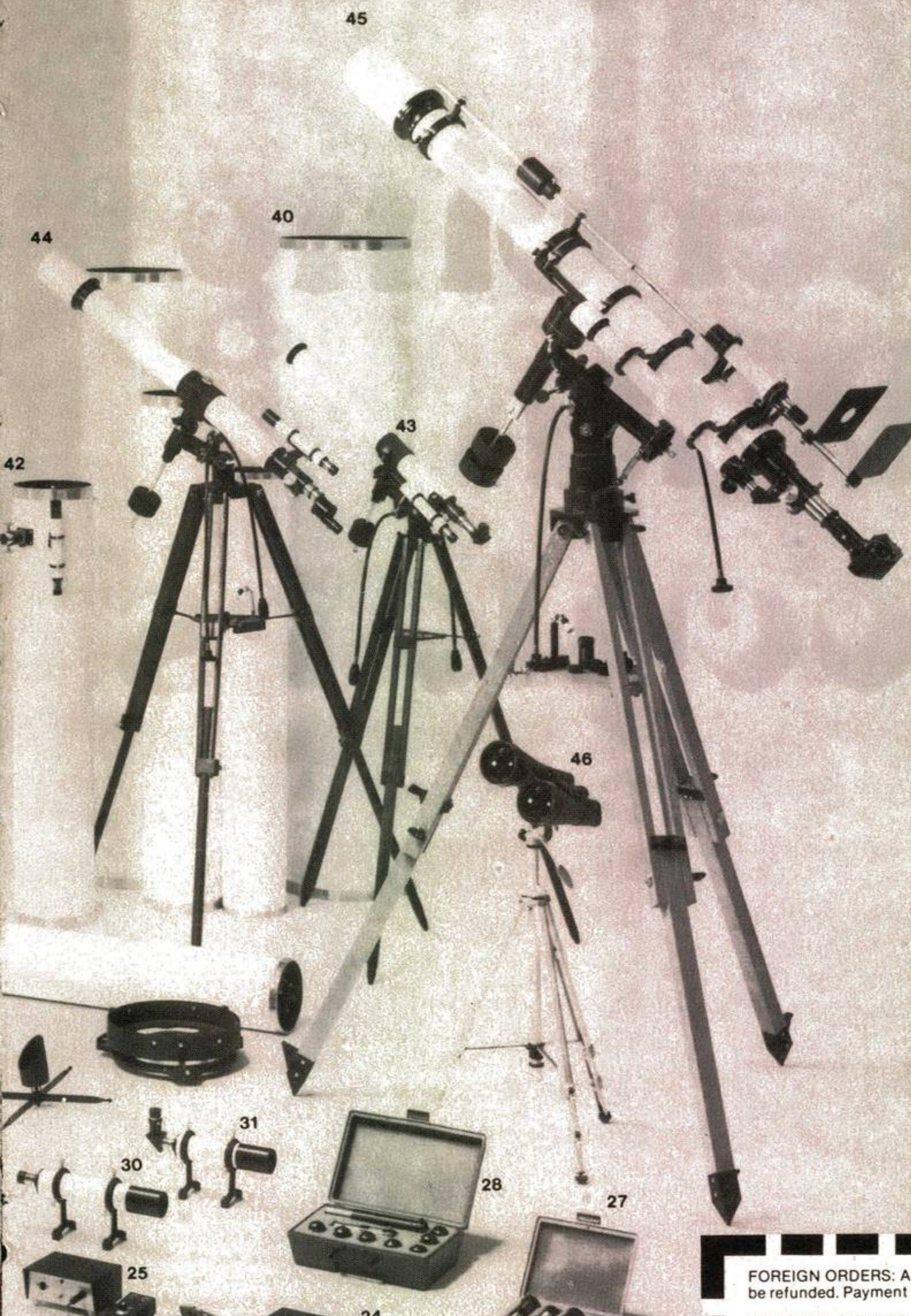

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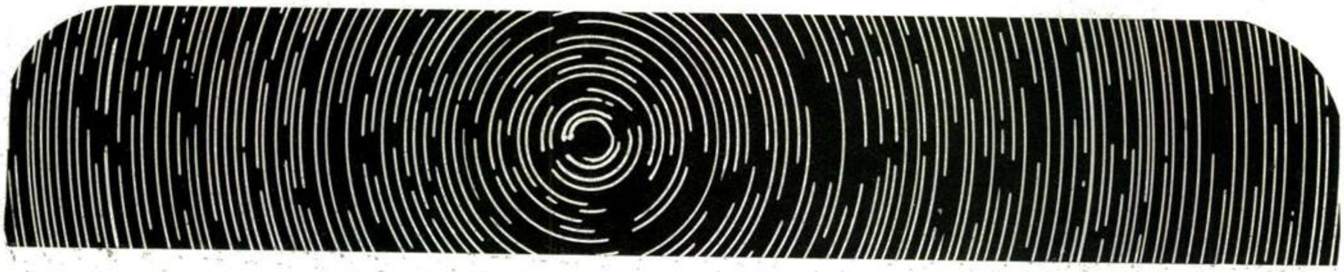


GAZER'S GAZETTE

Observing With Binoculars

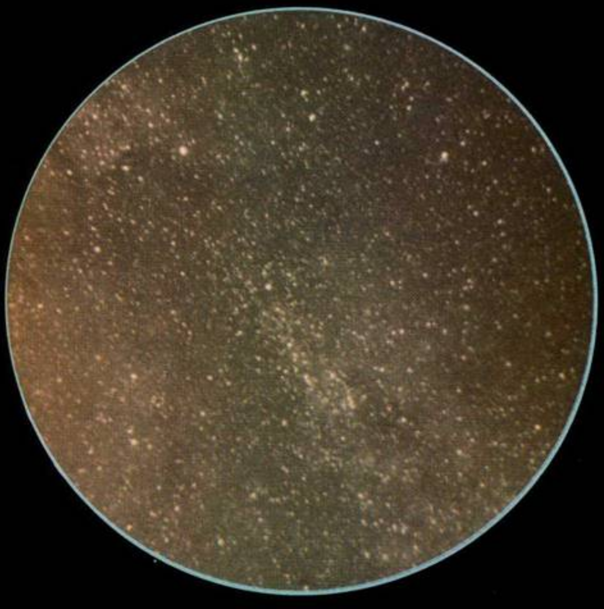
by

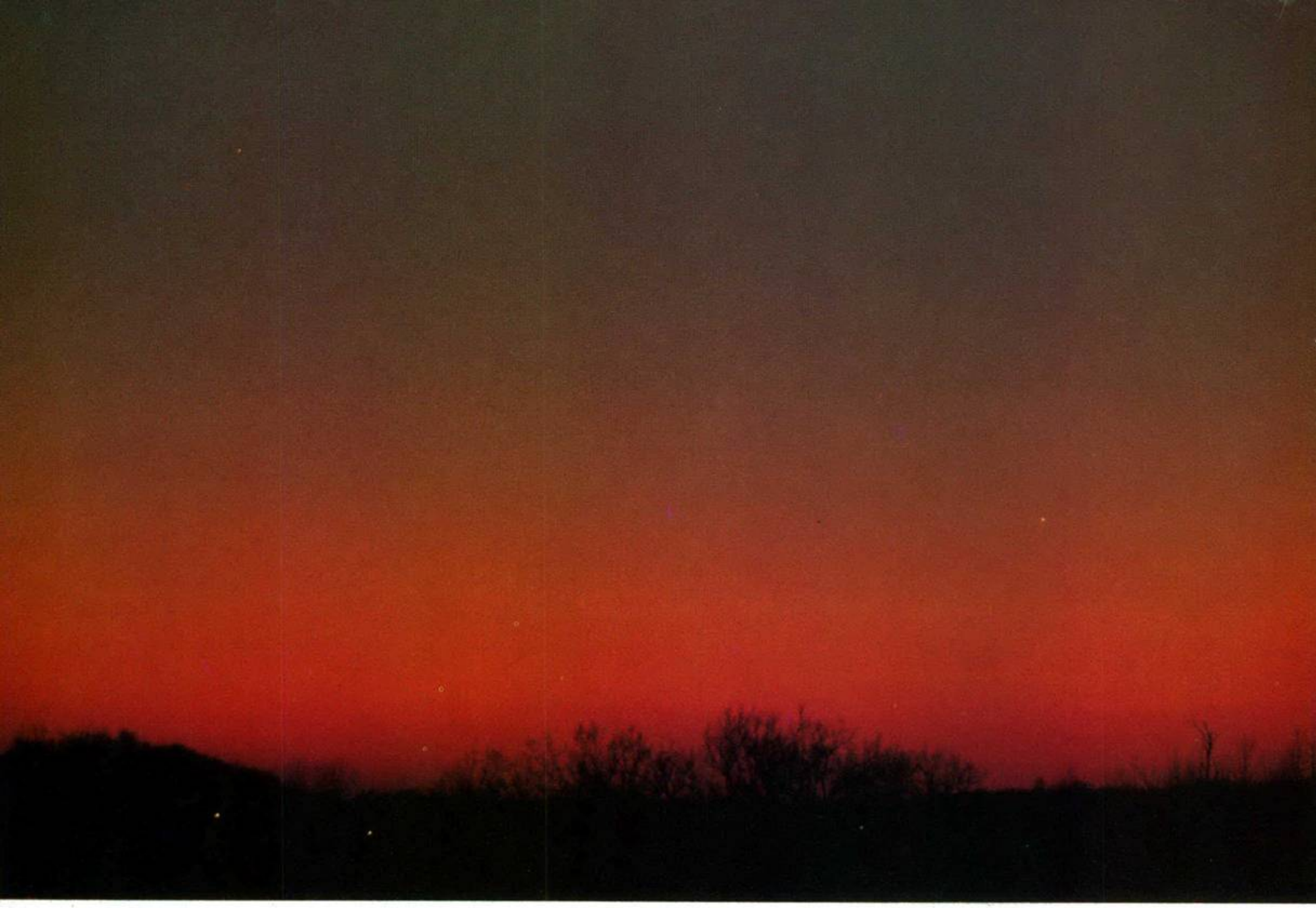
Henry J. Phillips

How does a person get started observing? Even those persons who have moved to a dark sky location, ground a 20 inch mirror, and set up their own private observatory were beginners at one time. They may have been intrigued by photographs in a book, or happened to notice a lunar eclipse — or they might simply have looked up at the night sky, and wondered. But no matter how it begins, it's safe to assume that someone is well on the way to becoming permanently hooked on astronomy when he picks up his pair of birdwatching or race track binoculars and turns them toward the stars.

The person who is doing this for the first time will initially notice only that "things get bigger". The moon will appear larger, stars more widely separated, and most constellations won't fit into the field of view. But as he looks further, he'll also find that the sky becomes more detailed: Craters and maria will appear on the moon where previously only dark and light sections were visible. Stars too faint to be seen with the naked eye will pop into view between the brighter ones, and that curious, ghostly sheen called the Milky Way will stunningly

These photographs approach the views of various celestial objects through binoculars. Upper left: Lunar eclipses are excellent subjects for binocular viewing; shown here is the total eclipse of May 24, 1975. Photograph by Charles Minnich. Upper right: More powerful binoculars give an excellent introduction to lunar features. Photograph by Steve Reed. Center left: Comets can be spectacular in binoculars — especially the rare ones like comet West. Photograph by Howard McCallan. Center right: Some small constellations, such as Lyra, will fit into the field of view and show many more stars. Photograph by Rick Albrecht. Lower left: The Pleiades and other large open clusters are viewed to best advantage in binoculars. Photograph by Jon Hanford. Lower right: Sweeping through the Milky Way with *binoculars* is an absorbing pastime. Shown here is the Cygnus region. Photograph by Ewell Schirmer.





When planets or bright stars are located low over the horizon at sunrise or sunset, it's often difficult to pick them out through the twilight with the naked eye. Searching for such objects with binoculars makes this particular game of hide-and-seek more fun and easier to win. Shown here are Mercury (left) and Venus, glowing faintly through the reddening sunset sky. Photograph by Brad Timerson.

reveal itself to be composed of millions upon millions of individual stars.

All *this* can be seen with a simple pair of binoculars? Yes indeed! Those "field glasses" that tend to sit in their cases between baseball games can be put to good use any clear night of the year. If the moon and stars are just beginning to pique your curiosity, there's nothing better than binoculars to serve as a launching point for a lifelong interest in, and love of, astronomy.

With the obvious exception of your eyes, binoculars are the world's most accessible instrument for stargazing. Almost everyone owns or has easy access to a pair. If you don't, you can readily find perfectly good binoculars in secondhand shops for as little as $25. They rarely wear out with time; the binoculars you have now will still be in excellent condition 20 years from now — even if you use them on every available night (and take care of them between times). In other words, binoculars are a great investment for the future.

The articles "Binoculars for Stargazing, Parts 1 and 2" (ASTRONOMY, January 1976 and March 1977) explained what binoculars are, how they work, and compared different types of binoculars. But what can you use them for in serious observing? What will you be able to see through them? Will the purchase of a telescope of any size make your binoculars obsolete? Does binocular observing have any inherent advantages over other instruments?

The answer to the last question is a resounding yes! For the absolute beginner, binoculars hold a decided edge over any more powerful observing tool — as we've already hinted. If you're just starting to learn your way around the sky and your knowledge of the constellations is still rather shaky, simply locating the groups' component stars in your binoculars will help fix in your mind the shape of, and brightness of the stars in, any constellation. Searching for bright stars is excellent practice as you gradually extend your horizons to the sky's dimmer objects.

Also, beginners often have trouble relating the appearance of an object through a large telescope — even at low power — to the sky itself. For example, suppose a friend points out to you the location of M-31 (the great galaxy in Andromeda), and you see a fuzzy spot — or, worse, nothing at all. If your next step is to look through a huge reflecting telescope and see M-31 in all its radiant majesty, the apparent lack of relation between the blank spot in the sky and the huge galaxy in the telescope can easily prove bewildering. The transition between the naked eye and a telescope is frequently too great for the beginner; binoculars make for a much quicker adjustment. Binoculars are properly the next step up the scale from the naked eye.

In short, binoculars are a most effective teaching aid. If you're helping someone get started as an observer, there's nothing like a pair of binoculars to help him over the rough spots and get him acclimatized to the idea that "there's more here than meets the (naked) eye."

Another purely practical advantage of binoculars is their portability. Even if you can't possibly squeeze your smallest telescope into the car before you leave on a camping trip, you can still find room for binoculars atop the pile of equipment, tucked into your sleeping bag, or on somebody's lap. Where weight considerations are a factor, such as on an airline flight, bringing along the binoculars will prove a lot simpler — and give everyone involved fewer headaches — than most "portable" telescopes. This is why vacation time is ideal for observing with binoculars; you not only have more leisure time for observing of any sort, but binoculars are the equipment you're most likely to have along with you.

Practicality is also a byword when it comes to a seldom discussed problem many beginners face — simply adjusting their eyesight to looking through optical instruments. Long-time observers will probably have forgotten, but the beginner faces a certain amount of difficulty in looking through a small aperture eyepiece. Obviously, it's easier to use two eyes than one, and while you can obtain instruments for using eyepieces in tandem on a telescope, binoculars are the best readily available solution to the perpetual problem of eye training. The use of two eyes will lead some observers to notice a three-dimensional effect through binoculars; for example, the moon will appear to stand "in front of" surrounding stars, or bright stars or clusters will look nearer than fainter ones nearby. It's an optical illusion, but somehow it adds to the enjoyment that binoculars give.

Once you've brought your binoculars out under a clear, dark sky, exactly what can you expect to see through them? The answer will vary depending on the size; a pair of 20 x 80 monsters will let you see a lot more than 7 x 50s. However, it's much more likely that you'll be using 7 x 35 or 7 x 50 binoculars — if for no other reason than they're much easier to find, handle and use. The following statements on what you can expect to see are based on a pair of 7 x 50 binoculars.

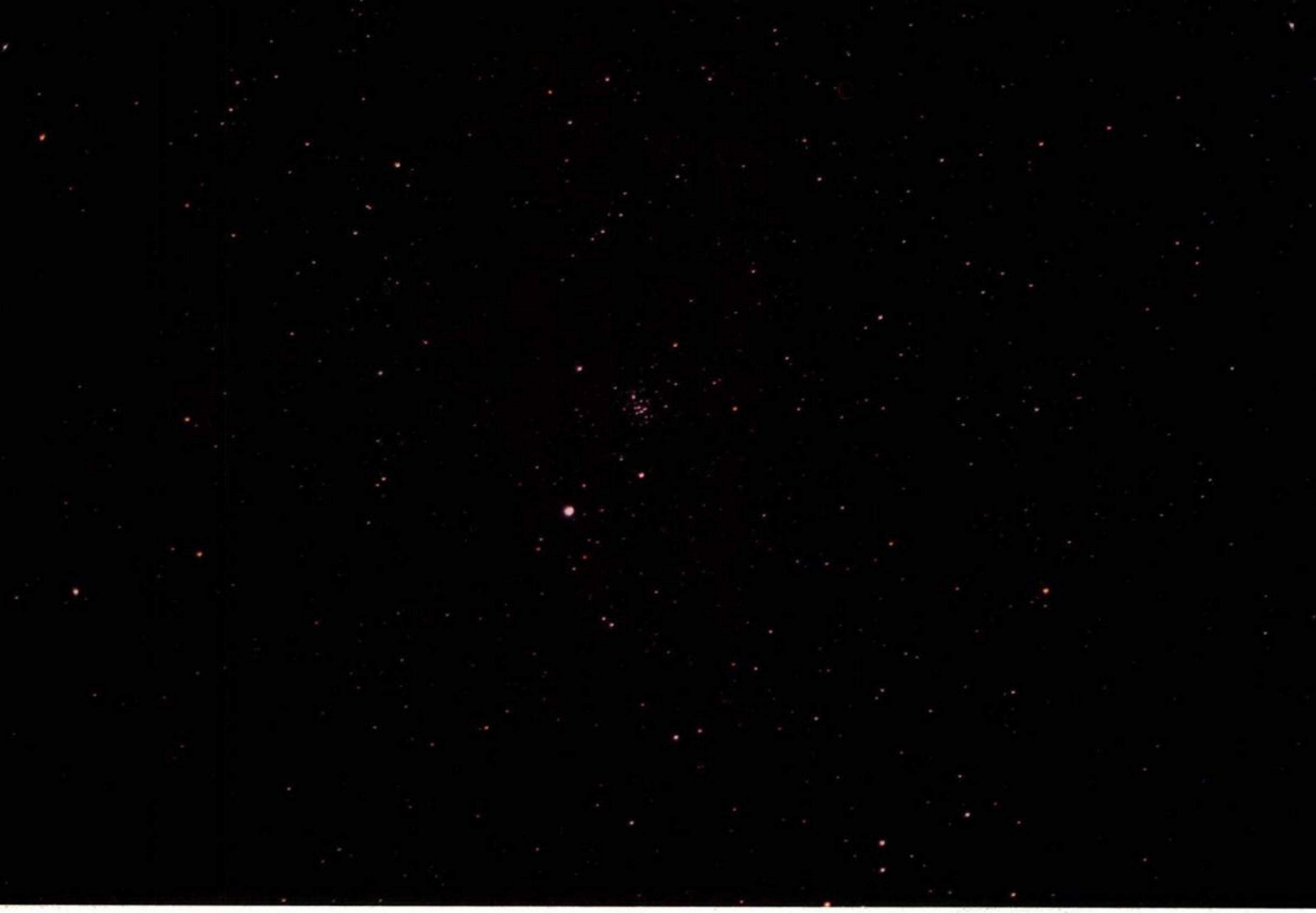
The moon is a prime candidate for binocular observing. You'll be able to see enough detail to familiarize yourself with the major craters and maria. If you're just beginning, work without a lunar map at first, and get yourself used to the notion that those jolly features you've been associating with the "man in the moon" are actually extensive lava fields and huge craters. When you've done this, look up the names of the larger features. You'll soon be able to easily distinguish the Mare Nectaris from the Mare Tranquilitatis, and you'll learn which crater is Clavius and which is Copernicus. Later, if you acquire a telescope, you can study the moon's face in greater detail; using binoculars, however, will help you quickly learn the moon's most important and largest features.

Eclipses are ideally suited for binoculars. If you're lucky enough to be able to witness a total solar eclipse, binoculars will provide a clearer view. A solar eclipse, however, is a short, fast moving event, and your time is likely to be taken up getting photographs instead of actually looking at it. Lunar eclipses, on the other hand, last for hours, are much slower paced, and a lot less hectic. You can take time between photographs for long, leisurely looks through your binoculars. There's nothing more relaxing than spending an evening with friends on chaise lounges in the backyard, passing around the binoculars so everyone can enjoy the sight of the moon gradually growing dark and copper colored. Many observers enjoy keeping record of the times of immersion and emersion (entrance into and departure from Earth's shadow) of the various lunar features; binoculars are a minimum requisite for this activity.

You can also enjoy the planets with binoculars. True, you won't be able to distinguish much more than you can with the naked eye; for that, you'll need a telescope. But such events as planetary conjunctions or close approaches of a planet to the moon are probably more exciting in binoculars than with the naked eye. If two objects, when seen through "enlarging" binoculars, still appear close together, they *seem* closer. You can test this remark this month, when Venus and Mars are within 1.2 degrees of each other on the morning of June 3.

This brings us to another point. On those evenings or mornings when planets are close enough to the sun that it's hard to pick them out through the twilight, binoculars will make the task a lot simpler. Mercury, especially, will be visible a lot more often if you use binoculars to find it.

Later at night when the outer planets are high in the sky, take a look at them too. You can see the bright satellites of Jupiter in binoculars when they're far enough away from the planet. (A tripod will help here if you can't hold the binoculars steadily enough.) Some observers report a slight flattening of Saturn's image through binoculars — a more or less indirect sighting of the rings. And don't forget that you can easily pick up Uranus and the brighter asteroids through binoculars, too. Comets are probably better seen in binoculars than in any other instrument; their surface brightness is low, and binoculars won't dissipate their light as much as telescopes will.



An exciting sight in binoculars is the conjunction of two celestial bodies, whether they are two planets, a planet and the moon, or (as shown here) a planet and a cluster of stars. This photograph, taken March 19, shows the close approach of Saturn to M-44 (the Beehive cluster in Cancer), and approximates the view in low power binoculars. Larger field glasses may remove one of the objects from the field of view. Photograph by Terry Haave.

Turning now from the solar system to the stars, we find there are many other uses for our binoculars. As stated above, use of binoculars will aid greatly in your study of the constellations. Some small constellations — like Sagitta, Delphinus and Aries — will fit easily into the field of view, as will bright parts of larger groups, such as Orion's belt or the head of Draco. You can compare stellar colors and magnitudes easily through binoculars (the latter will come in handy for observations of bright variable stars).

Large open clusters that won't fit easily into a telescope's field of view are best viewed through binoculars. The Pleiades are the most obvious example; others are the Hyades and Coma Berenices. Viewing any of these three with binoculars will show you many more stars than with the naked eye, while keeping the cluster compressed enough so that it still looks like a cluster.

Many Messier objects are easily located in binoculars. M-6 and M-7 (two open clusters in Scorpius), M-44 (the Beehive cluster in Cancer), and M-42 (the Orion nebula) are simple to find and give excellent views. You can also pick up many objects that show up as fuzzy spots, including nebulae, globular clusters, and the brighter galaxies. This summer, don't miss M-8 (the Lagoon nebula) through binoculars; set against the glowing Milky Way background, the Lagoon is superb, and you'll return to it again and again.

Finally, one of the happiest occupations of the binocular user is sweeping the instrument slowly across the sky. The Milky Way is the best area of the sky for this activity. Just let your eyes travel along the crowded star fields; you'll notice new things every time, be they double stars, interesting star patterns, chains of stars, or blank "holes" that indicate the presence of thick dust clouds. Binoculars are ideal for Milky Way sweeping, particularly when you're not looking for specific objects but are merely enjoying the endless fascination of the dense collections of stars.

All astronomical instruments have some advantages unmatched elsewhere, and binoculars are no exception to this rule. If you go on to a telescope, don't put the binoculars away — keep using them! Whether you're a beginner or the most advanced stargazer, a good pair of binoculars can make you happy any night of the year.

Watch A Stellar Eclipse

by
E. Ray Grasshoff

It's not too hard to find someone who has seen a solar or lunar eclipse, but how many people do you know who have seen a stellar eclipse — the eclipse of one star by another?

Thousands of years ago, Arabian astronomers were amazed as they watched a star dim perceptibly one night and brighten the next. Today we know this star as Algol, which is probably derived from the Arabic "al Ghul" meaning "demon" — indicating how terrifying the sight must have been. (All the other stars they could see shone steadily and did not change their brightness.)

You, too, can feel the awe of those early astronomers by watching Algol on successive nights. And the next day you can tell everyone that you spent the night observing an eclipse!

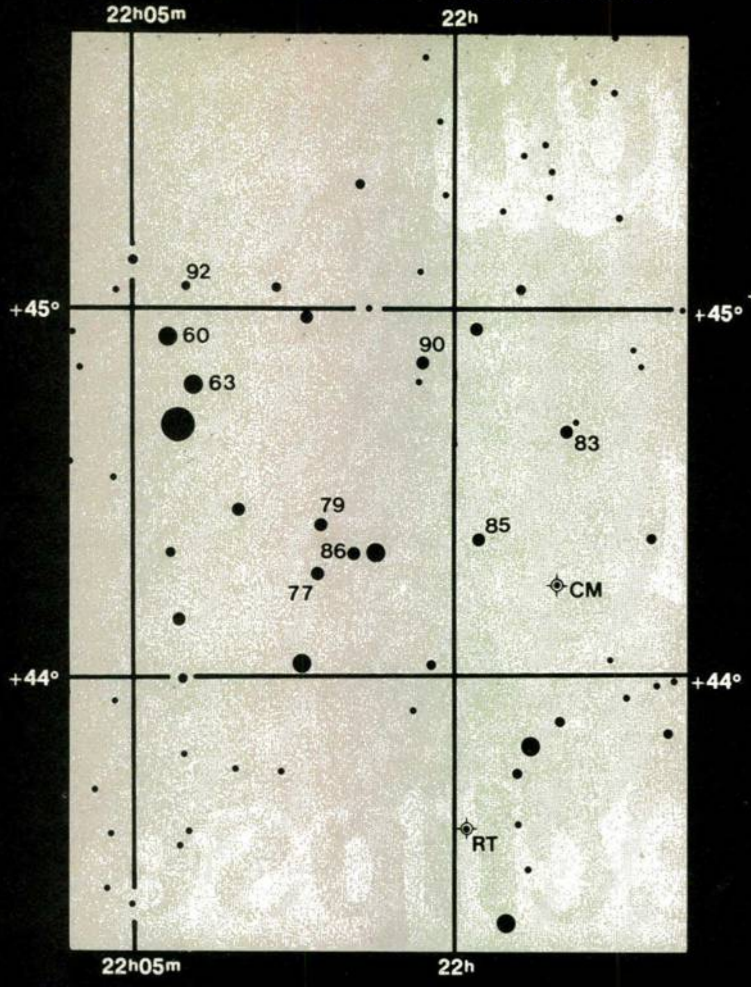
Algol is actually a multiple star system — in this case a double (binary) system. Stellar eclipses can only occur in such systems. Since astronomers estimate that at least half of all the stars in the sky are multiple stars, it would seem that stellar eclipses would be quite common. Indeed they might, but we need a special type of multiple star — called an *eclipsing binary* — for there to be a stellar eclipse. This type of binary consists of two stars orbiting each other. The orbital plane must be edge-on (or nearly so) to our line of sight on Earth; otherwise, one star will never appear to pass in front of or behind the other, and no eclipse will be visible to Earthlings.

Some multiple star systems require centuries to complete a single orbit, while others are compact enough that an orbit only takes days (Algol is the best example). Still others have orbital periods of only a few hours.

As seen from Earth, all these eclipsing binaries seem to be single stars that dim periodically. How, then, do we know that each is actually a pair of stars in orbit around one another?

When astronomers discover a new variable star, there's no way of immediately telling what kind of variable it is. But its *light curve* makes the job easier, especially if it's an eclipsing binary. The

CM LACERTAE R.A. 21h58m03s (1950) Dec. +44°18.6'


22h05m
22h
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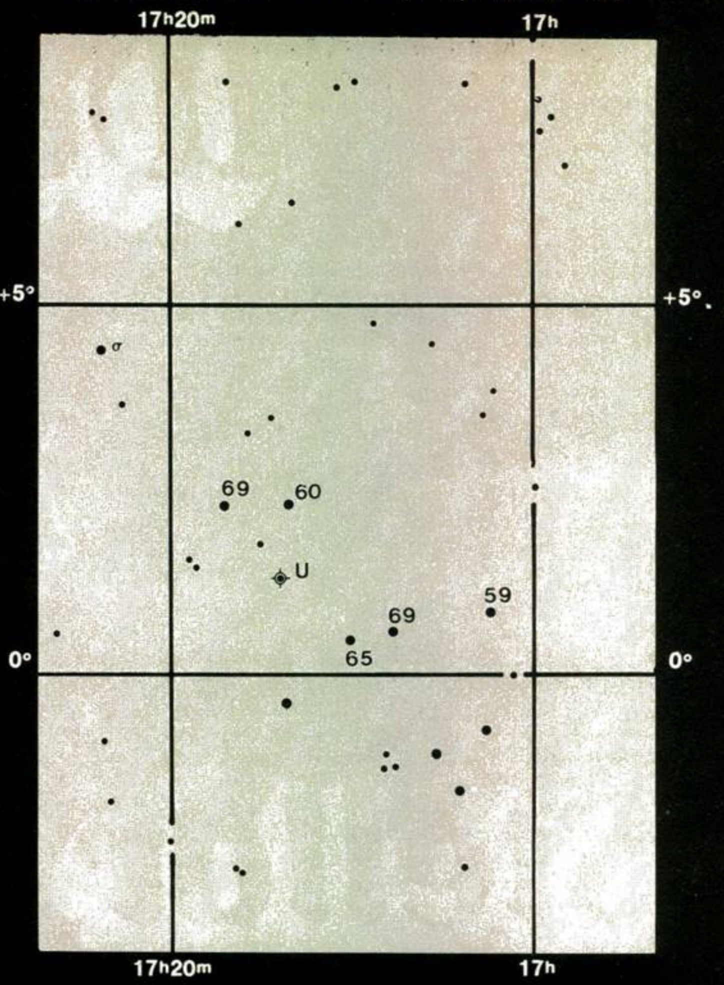
U OPHIUCHI R.A. 17h13m59s (1950) Dec. +01°15.8'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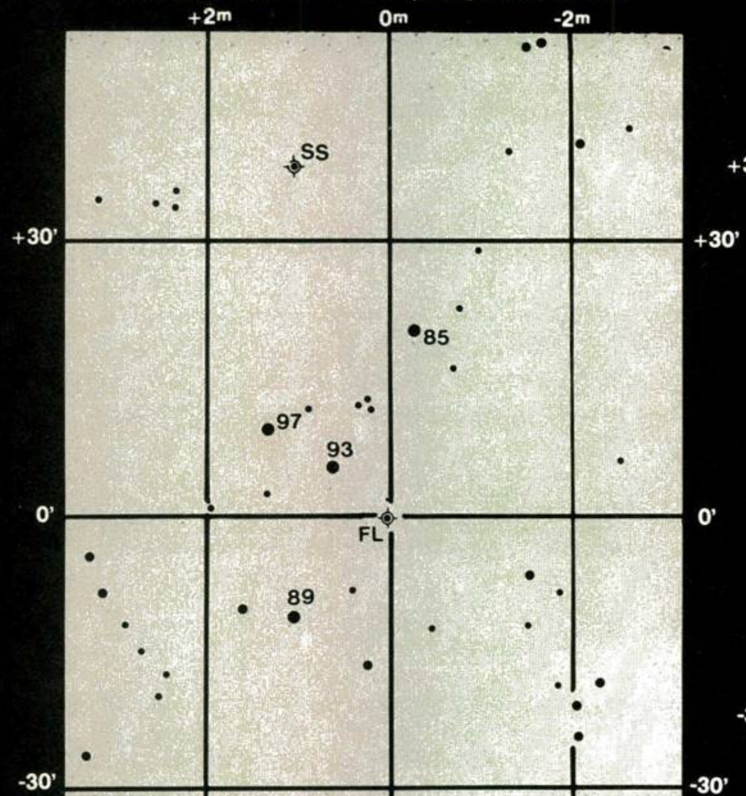
FL LYRAE R.A. 19h10m38s (1950) Dec. +46°14.1'


+2m
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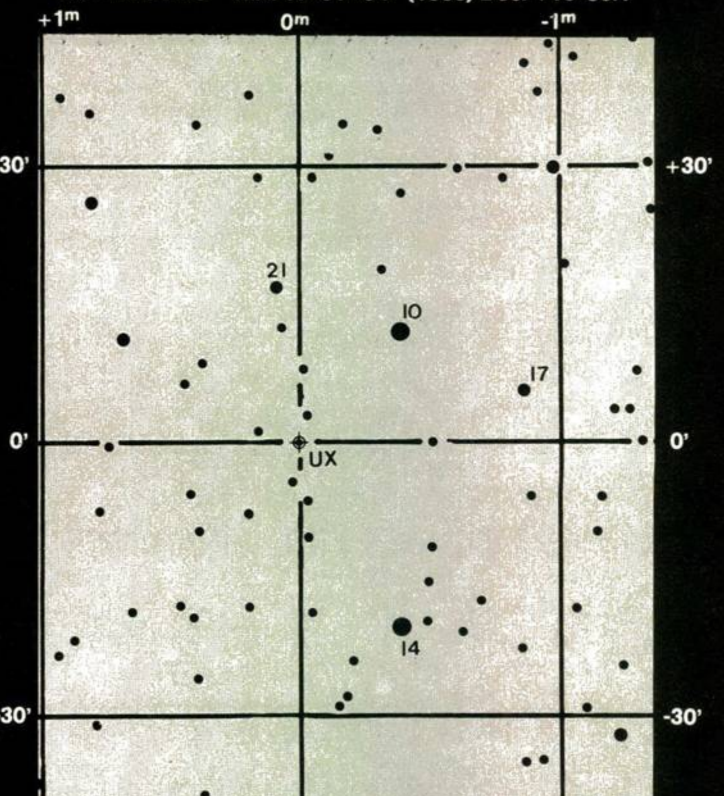
UX HERCULIS R.A. 17h51m54s (1950) Dec. +16°56.1'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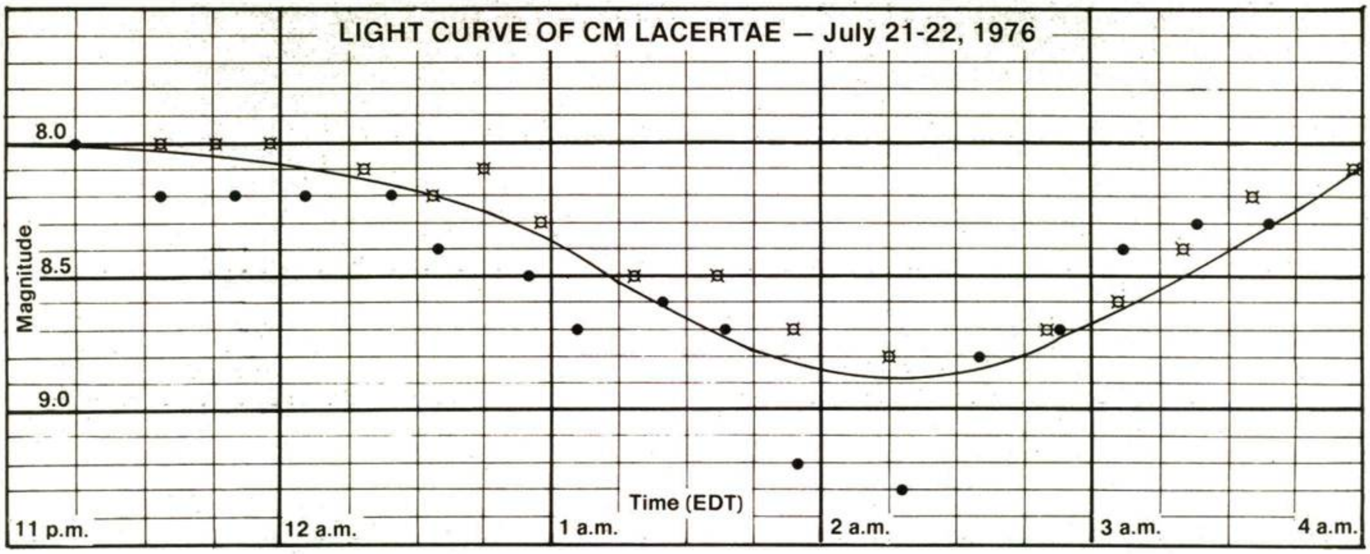
Maps drawn to different scales.



The maps (opposite) of four eclipsing variable stars demonstrate different methods of locating stars and estimating magnitudes. Maps for CM Lacertae and U Ophiuchi use conventional coordinate systems, while those for FL Lyrae and UX Herculis are centered on the variable. Coordinate lines proceed in equally spaced steps outward from the star. An observer of a variable estimates its magnitude by comparing it to surrounding stars of known brightness, using either a magnitude sequence or a step sequence. In the latter (as shown in the UX Herculis map), nearby stars are assigned arbitrary numbers, and the variable's brightness is estimated in relation to these. The diagram above is a typical light curve; two observers (using different symbols) chart their magnitude estimates and observed times for the star CM Lacertae. Note how widely some magnitude estimates differ. Maps and diagram courtesy of the Milwaukee Astronomical Society.

shape of the curve reveals a remarkable amount of information about the star. For example, the two components of Algol are about equal in size, but different in brightness. When the brighter star passes behind the dimmer star, the total light of the system decreases to what we call *primary minimum.* When the dimmer star passes behind the brighter star, the total light of the system is decreased only slightly and is called *secondary minimum.* If a variable shows these two different minimums in its light curve, the odds are good that it's an eclipsing binary.

It's easy to make a light curve for any variable by plotting magnitude against time. Such a curve simply shows how brightness changes over a period of time. To draw a light curve, first obtain estimates of an eclipsing binary's magnitude as it goes through an eclipse. Make your estimates by comparing the star to other stars of constant and known magnitude in the same area. Detailed charts and maps will show such comparison stars, in addition to the variable itself.

As with any astronomical activity, the key to making your first observations is planning. A few nights before you make your first estimates of any variable star, locate it and its comparison stars precisely. If any of the comparisons seems wrong or missing from your chart, it's probably safe to ignore it. (Charts and maps can be wrong, although this is rarely the case for the more widely observed stars.)

Although most eclipses last a day or more, the greatest magnitude change occurs around mid-eclipse. This is the time that you should attempt observations. It's best to make an estimate every 10 minutes — which means you'll spend a few hours making magnitude estimates of the same star.

Even if the variable in question seems to be dimmer than the minimum value it's supposed to have, *jot down the magnitude you see — not what you think it should be.* This is essential for accurate estimates. Experienced observers can distinguish between brightness differences by as little as .1 magnitude, but if you're just beginning, you'll be doing well to be within .5 magnitude. You may also have trouble telling the difference between two stars of near equal magnitude when deciding which is brighter. The trick here is to look quickly from one star to the other. Usually the first estimate you make is the best one; second guessing often ends up with your estimating the brightness you expect the star to be, rather than making an objective estimate.

Since Algol is easily visible with the naked eye, you may wish to try it first. Usually Algol (also known as Beta Persei) is about magnitude 2.1, but about every 69 hours it dims to 3.4. Each primary eclipse lasts about 10 hours, but the biggest light change occurs around five hours "centered" on mideclipse. On a night when an eclipse is to occur, simply estimate its magnitude once every 10 minutes, and write down the magnitude and the time (to the nearest minute).

The next day prepare a graph with magnitude on the y-axis and time on the x-axis, and plot each observation to get the light curve. This is actually a partial light curve covering only the primary minima. A complete curve would show the entire period, including secondary minima. Your first try at ob-

Bright Summer Eclipsing Variables

Star	UX Herculis	CM Lacertae	FL Lyrae	U Ophiuchi
Period	1.54 days	1.60 days	2.17 days	1.67 days
Mag. Range	8.9 - 9.8	8.5 - 9.5	8.7 - 9.5	5.8 - 6.5
Duration	5 hours	4 hours	4 hours	7 hours
Eclipse Dates and Times	June 2, 12:30 a.m.	June 8, 1:00 a.m.	June 1, 11:30 p.m.	June 12, 11:30 p.m.
	June 5, 3:00 a.m.	June 16, 1:30 a.m.	June 4, 3:30 a.m.	June 18, 12:30 a.m.
	June 19, 1:30 a.m.	June 24, 2:00 a.m.	June 15, 1:00 a.m.	June 23, 1:00 a.m.
	June 22, 4:00 a.m.	July 2, 2:30 a.m.	June 28, 2:00 a.m.	June 28, 2:00 a.m.
	July 3, 12:00 a.m.	July 10, 3:00 a.m.	July 9, 12:00 a.m.	July 3, 2:30 a.m.
	July 6, 2:30 a.m.	July 18, 3:30 a.m.	July 11, 4:30 a.m.	July 8, 3:30 a.m.
	July 20, 1:00 a.m.	July 26, 4:00 a.m.	July 22, 2:00 a.m.	July 13, 4:30 a.m.
	July 23, 3:30 a.m.	July 31, 12:00 a.m.	Aug. 1, 11:00 p.m.	Aug. 3, 11:30 p.m.
	Aug. 2, 11:30 p.m.	Aug. 3, 5:00 a.m.	Aug. 4, 3:30 a.m.	Aug. 9, 12:30 p.m.
	Aug. 6, 2:00 a.m.	Aug. 8, 12:30 a.m.	Aug. 15, 1:00 a.m.	Aug. 14, 1:00 a.m.
	Aug. 9, 4:30 a.m.	Aug. 11, 5:30 a.m.	Aug. 17, 5:00 a.m.	Aug. 19, 2:00 a.m.
	Aug. 20, 12:30 a.m.	Aug. 16, 1:00 a.m.	Aug. 28, 2:30 a.m.	Aug. 24, 2:30 a.m.
	Aug. 23, 3:00 a.m.	Aug. 24, 1:30 a.m.		Aug. 29, 3:30 a.m.
	Aug. 26, 5:00 a.m.	Sept. 1, 2:00 a.m.		

Eclipse times are rounded off to the nearest half hour; eclipse durations are approximate. All times are EDT. Eclipse data courtesy of the Milwaukee Astronomical Society.

taining a light curve may be disappointing, but don't be discouraged; accuracy develops with experience.

As your light curves become better, you'll be able to calculate the observed minus calculated (O-C) time of the minima. The O-C is simply the difference between the predicted (C) time of minimum and the observed (O) time of minimum. The periods of eclipsing binaries are often calculated over a stretch of 10 or 20 years, so the O-C can tell you how much the star deviates from the predicted times of minima. Change in direction in an O-C curve indicates change in the eclipsing binary's orbital period.

If you want to observe an entire eclipse in one night, try the star RZ Cassiopeiae. Dimming from magnitude 6.4 to 7.8 every 1.1195 days, the eclipses last only 4.8 hours. Again, since there is very little change in magnitude at the beginning and end of the eclipse, about two or three hours around mideclipse should show the fastest and greatest change. RZ Cassiopeiae is bright enough to be observed with binoculars. Small telescopes with a wide field of view will also work well, since comparison stars can be included.

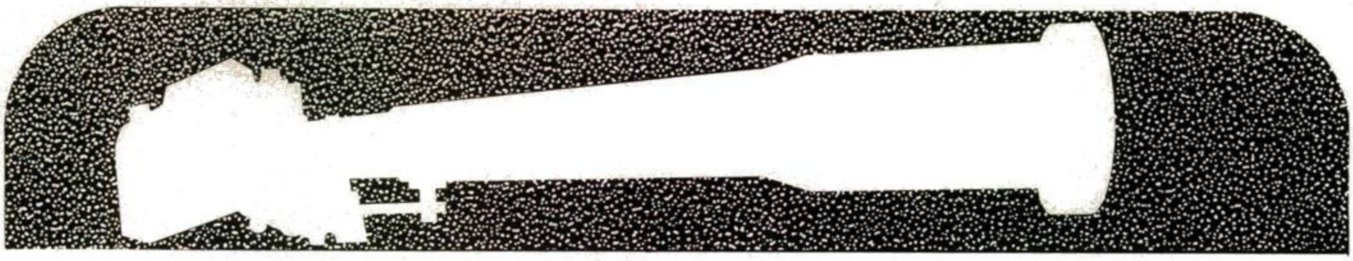
Members of the American Association of Variable Star Observers (AAVSO) report observations of variable stars — including eclipsing binaries — each month to AAVSO headquarters. You can get more information by writing AAVSO, 187 Concord Ave., Cambridge, Mass. 02138.

This star is especially interesting because its period sometimes changes — which brings us to another point. *Never let previous observations influence later observations!* Each estimate must be independent of all others, no matter how wrong it may seem.

Many different types of light curves will detail something a little different about a particular eclipsing binary. For example, if the bottoms of the minima are pointed, we assume that the eclipse is partial, since a total eclipse would produce a short time of constant light (characterized by a flat minimum). In such a case, the stars' orbital plane isn't edge-on as seen from Earth.

If a secondary minimum occurs halfway between two primary minima, we can assume the orbit is circular. But if the secondary minimum is shifted to a primary minimum, the orbit must be elliptical. Also, the relative depths of the primary and secondary minima can be used to get the ratio of the radii of the two stars.

With this data, a fairly complete geometric model of an eclipsing binary can be built. From further analysis of the system with spectroscopic equipment, we can get orbital velocities of individual stars. A star's surface temperature can be estimated with spectroscopic data, and scientists can use this with the geometric model to get luminosities and absolute magnitudes. From this, interstellar distances can be determined. In short, the enterprising astronomer can gain a surprising number of facts about the structure of stars from the study of eclipsing binary systems. ◆

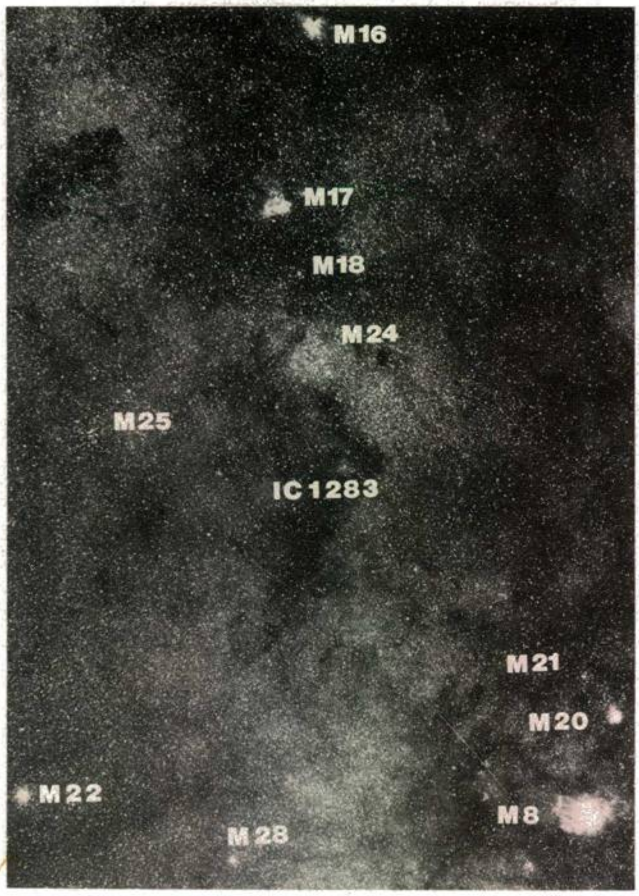


PHOTOGRAPHY IN ASTRONOMY

Spectroscopic Films in Color

Every deep sky astrophotographer knows the advantages of Kodak's spectroscopic emulsions: high speed with low reciprocity failure. Everyone bemoans the unfortunate fact that such useful emulsions can't be made into a color "monopack" (single three-color film) for color astrophotography.

However, it *is* possible, with some extra darkroom work, to reconstruct a color picture from three separate exposures made on spectroscopic films. On the following two pages is a beautiful example of what can be done: the Milky Way in Sagittarius, Scutum, and Serpens Cauda. It was photographed with a homemade astrographic camera (20 inches focal length at f/5) on spectrographic emulsion coated on 4 x 5 inch glass plates. The camera was designed and built by Rev. Ronald Royer, and the photographs were taken by Father Royer and Steve Padilla.

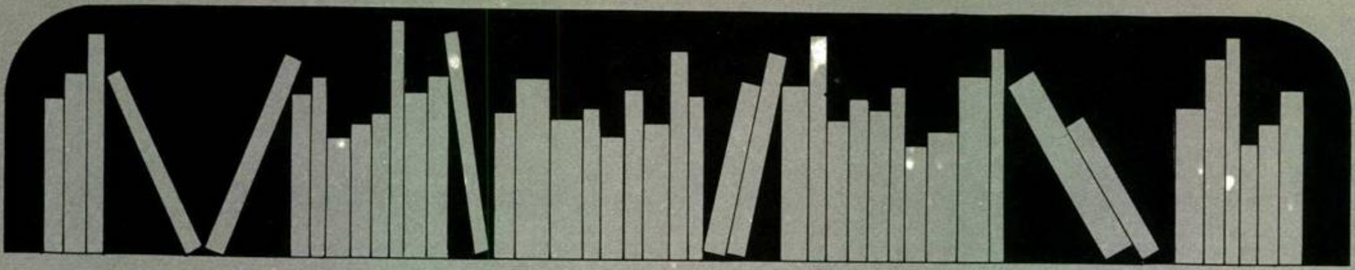


For this picture, a blue sensitive IIa-O plate was exposed through a Wratten 1A filter for 25 minutes; next, a yellow-green sensitive IIa-D plate was exposed through a yellow Wratten 8 filter for 30 minutes; finally, a type 098-02 plate (red sensitive) exposed through a Wratten 25 red filter for 50 minutes. The camera was carried into the California desert and hand guided on a portable mounting. Each of these black and white negatives is a beautiful and highly detailed picture by itself.

To "reconstitute" the color, ASTRONOMY made a positive film enlargement from each negative, and then photographed them successively on a lightbox — each through the appropriate color filter (red #25, green #58, blue #47) onto a normal color slide film.

How good is the color produced by this method? It's more contrasty than the actual appearance of the sky because most spectroscopic films are designed for high contrast. Faint details stand out from the background better than they naturally would if you had ultrasensitive eyes. Also, the supersensitive red film (type 098-02 spectroscopic plate) has more contrast than the blue or yellow-green plates. Therefore, the resulting color image reveals red hydrogen nebulae somewhat better than it "should".

But don't worry about these problems. Sit back and revel in a new way to capture the beauty of the sky. Look at the young blue open clusters (M-21, M-24, M-25), the middle aged and old globular clusters (such as M-22 and M-28), the brilliant H-II regions (M-8, M-20, M-16, M17), the hordes of average stars in the starclouds, and the murky orangish light that diffuses through the dustclouds which fill the middle parts of the picture. Here is a truly beautiful new way to visualize the sky. Of course, if we receive good response from our readers, we'll run more of these Milky Way pictures — so, let us know what you think.



ASTRONOMY REVIEWS

The Solar System
edited by SCIENTIFIC AMERICAN

145 pages, paperback, $4.95
W.H. Freeman and Company (1975)

During the past decade, the exploration of the solar system has provided one of the most magnificent chapters in intellectual history. This age of exploration — unprecedented since the 16th and 17th centuries — has seen men circle Earth and walk on the moon. Their machines have vicariously probed the solar system from Mercury to beyond Jupiter, revolutionizing our understanding of the origin and evolution of the planets, and especially of Earth. Unfortunately, most people — and the news media that serve them — have been too preoccupied with wars, famine, economic distress and politics to recognize and appreciate the grand adventure of which they are, and should be, a part. Among those who do understand the excitement of these times are the editors of **Scientific American**, who produced a special issue in September 1975 devoted to the solar system. These 12 articles, providing a comprehensive overview current to mid-1975, have been reprinted in **The Solar System.**

It would be difficult to imagine a more distinguished list of authors (including Carl Sagan, William K. Hartmann, and James A. Van Allen) to describe solar system research. All are authorities in their subjects, and are actively involved in the research upon which they report. Additionally, all write well, conforming to the usual **Scientific American** style and level of presentation. A very great deal of information is contained in these 145 well-illustrated pages, including bibliographies for each article and a good index.

Several general themes characterize the perspective of these articles. First is the unprecendented abundance of new data. For the sun we have x-ray photos from Skylab and neutrino measurements from deep in an abandoned gold mine in South Dakota; for Earth, a whole new framework provided by the concepts of plate tectonics and continental drift, and for our moon, the incredibly detailed studies being carried out with returned lunar samples. For the planets from Mercury to Jupiter, there is the wealth of data returned by United States and Russian spacecraft. It is difficult to remember, when reading of arguments on the chemical composition of lavas from the Martian shield volcanos, how very few years have passed since we were arguing over the reality of canals!

The second theme concerns chemistry and chemical evolution. Increasingly, prominence is given to questions on composition of interiors, surfaces and atmospheres, and to the conditions in the early solar nebula that would have been required to form the variety of planets, satellites and smaller bodies we see today.

Finally, many of these articles stress the relationships among objects — an area often called *comparative planetology*. Why do Mercury, our moon and Mars all have one hemisphere with plentiful lava flows and one without? Is it coincidence that Mercury, the moon, and Mars' satellite Phobos all have about the same density of craters on their surfaces? Why have Venus and Earth, with similar sizes and bulk compositions, evolved such drastically different atmospheres and surface conditions? What can the development of Martian duststorms tell us about terrestrial meteorology? These and many similar questions are now providing a new focus for planetary studies.

This book provides an excellent, up-to-date introduction to the solar system, as seen by its explorers in the midst of their initial voyages of discovery. *David Morrison.*

◆

Apollo/Soyuz Test Project Preliminary Science Report
edited by R. THOMAS GIULI

529 pages, hardcover, $12.50*
NASA (1976)

Once a space shot drops from the headlines, serious science begins in earnest; this standard process occurred with Apollo/Soyuz in July 1975. But as noted in ASTRONOMY, numerous astronomical experiments were conducted. While much material has been given to the media, and some has been published in technical journals, this NASA book gives the first summary of the preliminary results of these experiments.

The book covers the entire mission, with a general flight summary followed by detailed papers from each scientific team. Besides astronomy, experiments in meteorology, Earth resources, space medicine, biology, and space processing were also on the agenda. These reports comprise the majority of the book, as they took up the major part of the flight.

All experimental equipment is carefully described and illustrated. Both flight plans and actual flight results are given in detail. Some data (such as that from the helium glow detector) was still being reduced at the time this book was published.

The amount of space devoted to the astronomical experiments is probably not sufficient to solely justify purchasing this book. But there are other benefits, including writeups on space processing, Earth resources (with more than a dozen full page color Earth photographs), and medical tests.

Most important, this report is a memento of the first international manned space mission. Although the politics of the "handshake in orbit" were most in evidence during the flight, the scientific and engineering benefits are here for all to see. Important new equipment and methods for Space Shuttle operations were also tested (including a revolutionary new space-to-space tracking system which boosted communications coverage from 17 to 63 percent of each orbit). This report is a scientist's view of a real manned space science operation. *James E. Oberg.*

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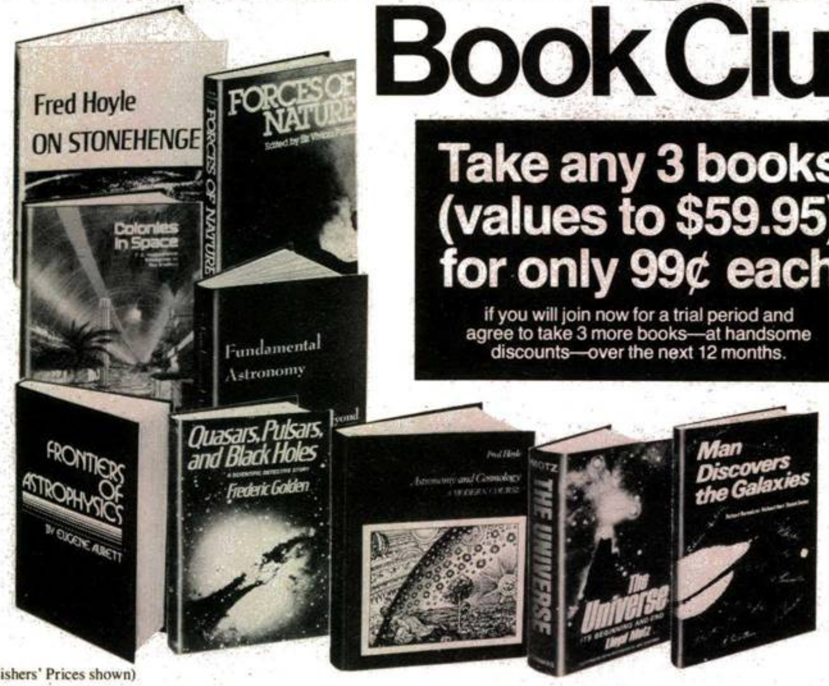

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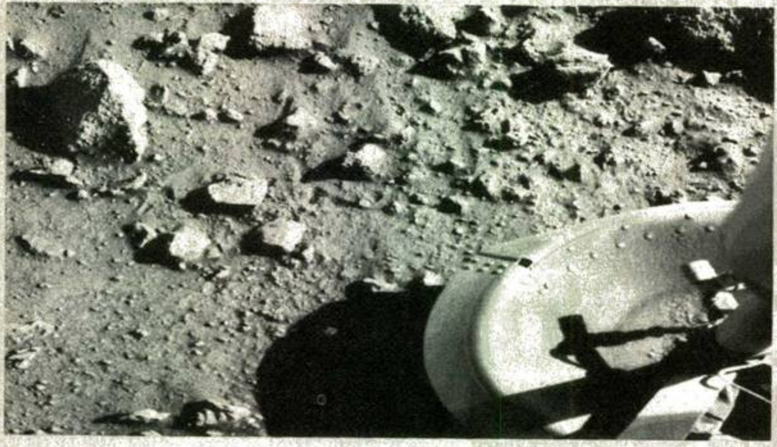

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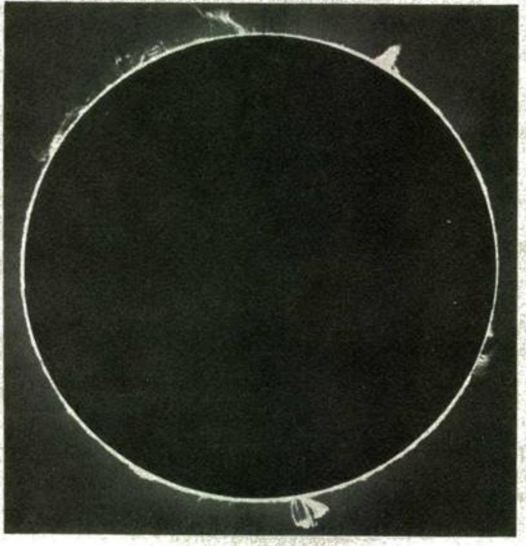

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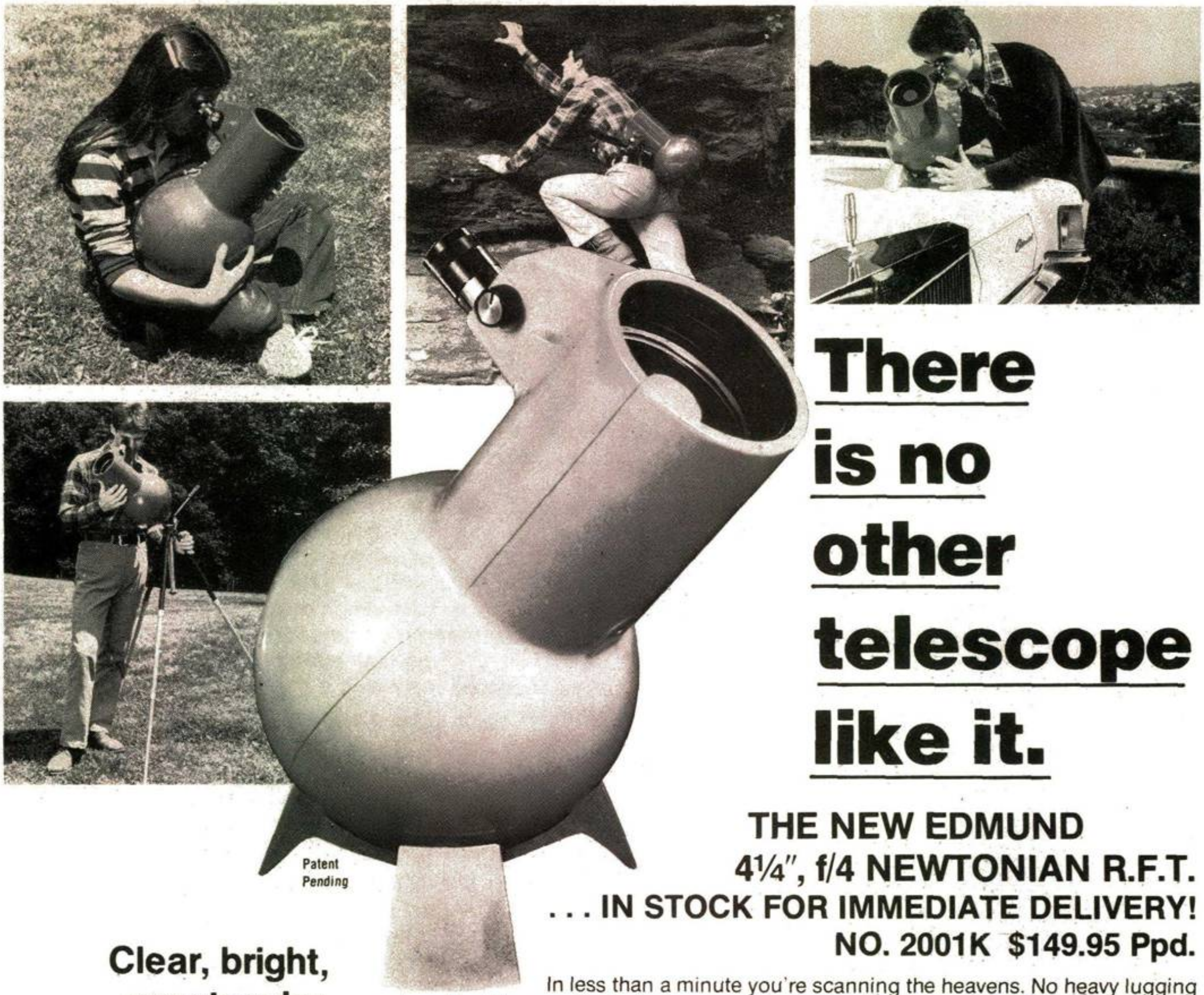

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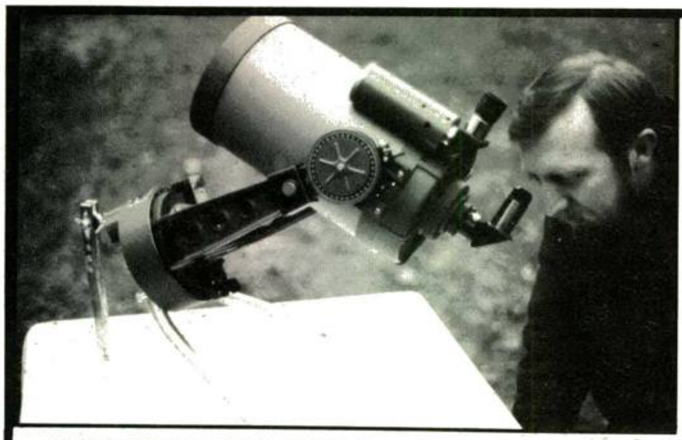

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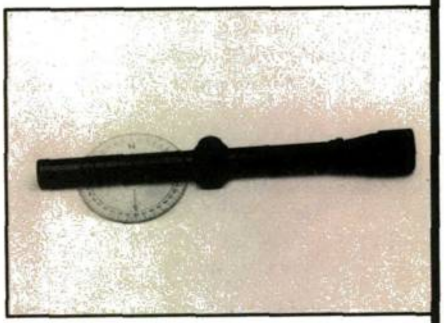

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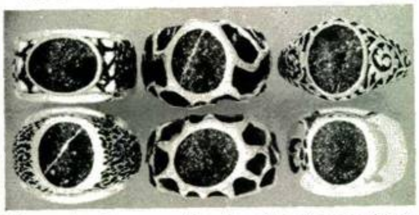

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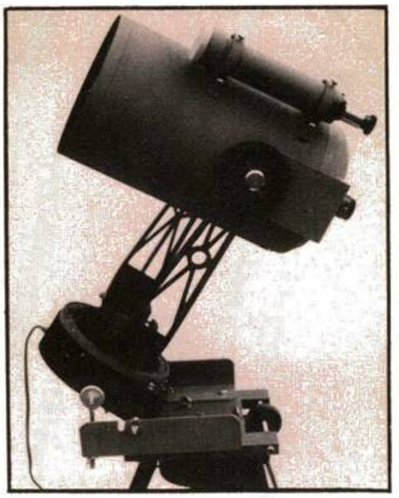

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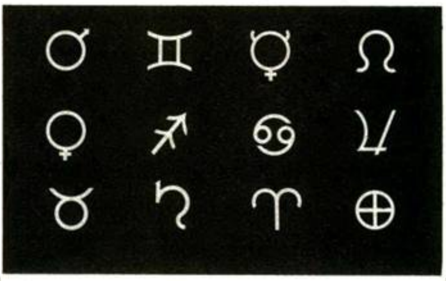

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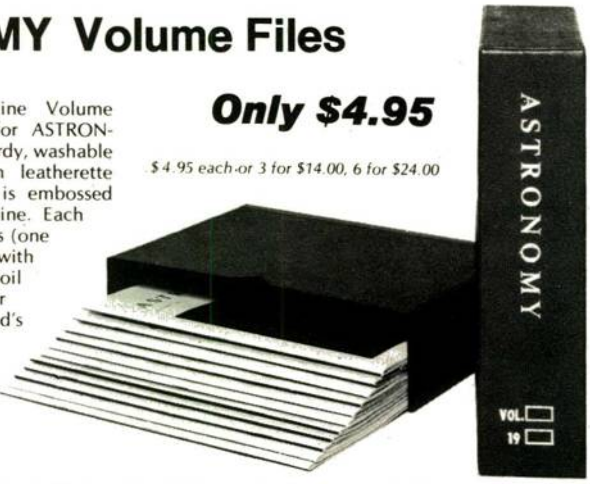

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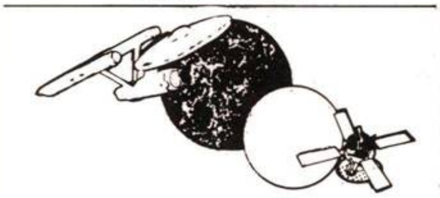

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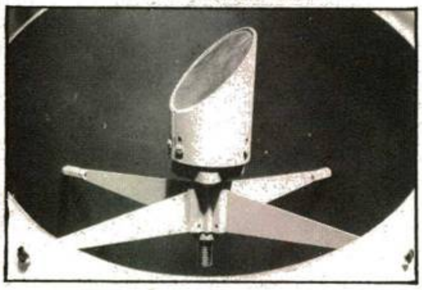

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WANTED — Mars globe. Write Joseph W. Morgan, 5118 W. Davit Ave., Santa Ana, CA 92704.

WANTED — Communication with Questar 7 owner to exchange performance information comparing it with Celestron 8. Write John Niedzialkowski, 1882 W. Windlake Ave., Milwaukee, WI 53215.

WANTED — Filar micrometer for use on Celestron 8. Please state specifications, availability, price. Write Harold J. Stelzer, 1223 Ashland Ave., River Forest, IL 60305.

WANTED — Back issues of ASTRONOMY: August 1973 through January 1976. Will pay $80.00 or more, depending on condition. Contact Alex J. Swidar, 55A Black Hawk Ln., Startford, CT 06497. Phone (203) 378-1019.

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WANTED — Programs or information on programs in Fortran or Basic for calculating cometary and/or planetary orbits from limited number of observations. Write Richard Zepernick, 12 Evans Rd., Cresskill, NJ 07626.

WANTED — Pen pal (preferably female; ages 14 to 16) interested in astronomy, astrophotography, extraterrestrial life, flying. Write Seth Horowitz, 169 Bradley Rd., Scarsdale, NY 10583.

WANTED — Back issues of ASTRONOMY. Single issues or sets considered. State date, condition, price. Also indexes to Volumes 1 and 2. Write Alan Morton, 3083-K Colonial Way, Chamblee, GA 30341.

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WANTED — Books, periodicals on UFOs and Fortean subjects. Send list only. Also contact with persons interested in researching historical (pre-1947) UFO reports and other types of unexplained phenomena. Write Lucius Farish, Rt. 1, Plumerville, AR 72127.

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POSITION WANTED — With science or science fiction publisher. 3 years editorial experience with scientific journals, books. B.A. physics. Extensive astronomy, general science background. Widely read in science fiction. References available upon request. Write Jeffrey Robbins, 144-32 35th Ave., Flushing, NY 11354.

ANNOUNCEMENT — Join the Johnson Space Center Astronomical Society for solar eclipse expedition from Houston/Miami to Colombia (Oct. 9-15). Contact ECLIPSE, c/o Paul D. Maley, 3615 Ledgestone Dr., Houston, TX 77059. Phone (713) 488-6871.

ANNOUNCEMENT — National Amateur Astronomers' Convention will be held Aug. 10-13, 1977 at University of Colorado in Boulder, with participation of AL, ALPO, IOTA, WAA. For information, write Denise Nye, NAA Convention Registration, 5604 Bowron Pl., Longmont, CO 80501.

ANNOUNCEMENT — Delaware Valley Amateur Astronomers (Philadelphia area) is seeking interested amateurs. Activities include group star parties outside the city, club trips to area observatories, ATMs, regular meetings. Contact Bill Shuman, 5018 Greene St., Philadelphia, PA 19144. Phone (215) 843-7279.

ASTRONOMY

Guide to Back Issues

Reader interest in back issues of ASTRONOMY magazine is higher than ever. As a result, our stock of back issues is swiftly dwindling. Below is a guide to ASTRONOMY back issues that are still available. For your convenience it is updated monthly; issues not listed are depleted.

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ASTRO-NEWS

Latest News From the World of Astronomy

Scientists Discover Very Large Stony Meteorite in Antarctica

The largest meteorite ever found in Antarctica — and one of the world's larger such finds — has been discovered by a United States-Japanese field party near a desolate ice covered mountain. The shiny brown chunk of rock, weighing 898 pounds (407 kilograms), was one of 11 stony meteorites found in December 1976 and January 1977.

The Antarctic meteorite was found in 33 pieces scattered on top of the ice over about two acres in the Transantarctic Mountains. The discovery site is in Victoria Land, about 120 miles (190 kilometers) northwest of McMurdo, the principal U.S. scientific outpost in Antarctica.

The scientists making the discovery were Drs. William A. Cassidy of the University of Pittsburgh, Edward J. Olsen of the Field Museum of Natural History of Chicago, and Keizo Yanae of the Japanese National Institute of Polar Research in Tokyo. The scientists disclosed their finding to the National Science Foundation, which funds and manages all American research in Antarctica.

Meteorites are masses of stony or metallic material which have survived their flight from space through Earth's atmosphere, and have fallen to the ground. They are important to scientists studying the origin and evolution of planets and their moons.

There are two principal hypotheses about the origin of meteorites. According to Cassidy, one is that they originally were parts of much larger celestial bodies, such as planets or moons. If this is true, he said, scientists examining meteorites would be looking at the bits and pieces of the inside of former planets or moons. The second hypothesis is that meteorites are a primordial accumulation of matter that never got together to form planets or moons. If this is so, then scientists would be looking at the initial processes that led to the formation of such bodies.

The 11 meteorites weighed a total of 1,015 pounds (460 kilograms), and included a metallic type of about 3 pounds (1.4 kilograms). They were found lying exposed on bare ice surfaces in places where the continental ice mass has lost its snow cover, apparently worn away by very strong winds. The very old ice exposed in such areas has a bluish color. The ages of the meteorites are not yet known.

"Of the dozens of blue ice areas studied," Cassidy said, "only two yielded meteorites. In the first area, two specimens were found 1/2 mile (.8 kilometer) apart; the other had nine within an area of about 30 square miles (80 square kilometers). These two areas contain much higher local concentrations of meteorites than are found in the rest of the world."

This search for meteorites in Antarctica was initiated as a result of the accidental discovery in 1969 of a similar concentration of meteorites by a Japanese team of glaciologists. During several field seasons, Japanese scientists have searched a large patch of blue ice some hundreds of square miles in area, and have recovered 992 meteorite fragments. According to Yanai, this may represent as many as 330 individual meteorites.

Prior to this discovery, there were only about 2,000 other known meteorite falls and finds in the rest of the world, Cassidy said. As evidenced by these most current discoveries, the Antarctic continent now appears to be an area that lends itself more readily to the collection of meteorites than other parts of the world.

Under a prior agreement, half of the meteorites went to Japan, and half to the U.S.

Spacelab Scientists Selected

Scientists representing the United States and 14 other countries have been selected to participate in the first Spacelab flight in 1980.

The group of 222 was chosen by NASA and the European Space Agency (ESA) from more than 2,000 candidates who responded to invitations to participate in the jointly planned NASA/ESA mission.

Scheduled to be launched into Earth orbit aboard NASA's Space Shuttle in the second half of 1980, the European built Spacelab is designed to allow workers to live and perform experiments in space economically and frequently.

The primary objective of the first flight is to verify the performance of Spacelab systems and subsystems, and to measure the environment surrounding the Shuttle.

The secondary objective is to obtain valuable scientific applications and technology data, and to demonstrate the broad capability of Spacelab to perform space research. Stratospheric and upper atmosphere research will be emphasized on this flight. Experiments also will be performed in plasma physics, biology, botany, medicine, astronomy, solar physics and Earth observations, and in technology areas such as thermo-dynamics, materials processing and lubrication.

Spacelab 1, a reusable laboratory, will consist of two main elements: a pressurized module and a pallet. The pressurized module is the laboratory where the scientists will work. It will have a "shirtsleeve" environment to make work as pleasant and as nearly like that of an Earth based laboratory as possible. For instruments that require exposure to space, Spacelab provides a series of pallet segments in the payload bay. In addition to serving as a mounting platform, pallets

Spacelab *continued on page 68*

Shuttle External Fuel Tank Possible for Space Platform

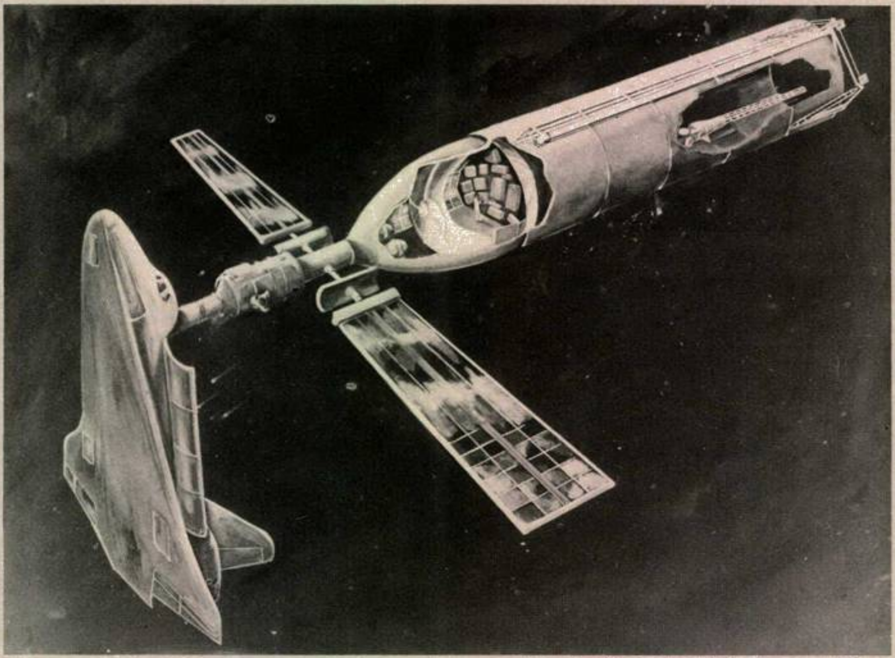
The only element of the Space Shuttle designed to be expendable may instead become an important part of a permanent space platform.

James Kingsbury of Marshall Space Flight Center said it will soon be necessary to develop a space platform to accommodate man's continuing presence in space.

One of several options being studied at Marshall is the possibility of the Shuttle External Fuel Tank (ET) going into orbit with the Orbiter, separating and becoming an orbiting vehicle — the nucleus of a permanent space platform. "From this permanent space platform," Kingsbury said, "the real business of space utilization can begin."

He proposed that some of the liquid oxygen propellant in the external tank would be off-loaded prior to launch. This off-loading would provide a separate compartment of approximately 2,000 cubic feet (57 cubic meters) that could be equipped on the ground for 90 days of crew habitation in orbit. A first Shuttle would carry such a tank into orbit and park it.

A second Shuttle launch would carry into orbit a Skylab Airlock Module and Multiple Docking Adapter along with a solar electric conversion wing. These elements would be docked and clustered to the waiting ET. The launch would also bring up the crew to inhabit the platform, and an additional 90 day supply of expendables to support a crew of three for six months without resupply.



Marshall Space Flight Center illustration

The work of the first crew would include construction of additional crew quarters in the remaining volume of the liquid oxygen propellant tank.

"Employing this concept," Kingsbury said, "studies have shown that a permanent space platform can be placed in a three-to-five year orbit with reboost capability. The platform can be expanded in a number of ways, using additional expended ETs or Spacelab modules or both."

This space platform would provide ample laboratory space to begin at least pilot production of the kinds of products envisioned in the space processing program. In addition, the ET hydrogen tank could be converted into a large space structure's manufacturing facility.

Kingsbury said that the studies are far from complete at this time, but that all elements so far investigated appear to be promising.

As a target, the studies are directed to an initial launch during 1983-84.

Stressing extensive use of space-qualified hardware, Kingsbury said that it is believed that a major space platform could be placed in Earth orbit in an early time frame, at a fraction of the cost associated with a new developmental program.

Kingsbury said, "One can readily recognize that the concept being studied does not differ significantly from that pursued by NASA in the development of Skylab. It is anticipated that the lessons learned from experience gained during that program will have direct application here, and the benefits and experience derived from Skylab can be applied by many of the same people in the development of an early space platform."

Spacelab

continued from page 67

provide power, thermal conditioning, data and other services to the instruments. Spacelab 1 will have one pallet, but as many as five may be flown at one time.

Spacelab 1 will be launched from Cape Canaveral, and will remain in the Shuttle Orbiter's cargo bay as it orbits Earth at an altitude of about 155 miles (250km), with an inclination of 57 degrees. The flight will last one week.

After the Orbiter reaches its proper orbit, the necessary Spacelab systems will be activated and tested. Then the payload specialists, working with the Orbiter crew and the scientific and technical investigators on the ground, will perform various experiments until the Spacelab systems are shut down in preparation for return to the landing site. The two payload specialists, an American and a European, will work complementary shifts so that scientific experimentation can continue 24 hours per day.

Of the 86 investigators chosen by NASA, 81 are from the U.S., and the others are from India, Japan, Canada, France and Belgium. The remaining 136 scientists selected by ESA come from 10 ESA member states, plus Austria and Norway.

Landsat Satellite

NASA and the Department of the Interior's Bureau of Land Management (BLM) will use the Landsat satellite to inventory wildland resources in the remote areas of Alaska, Arizona and Idaho.

The three part cooperative experiment will test and implement a system using Landsat information to provide the BLM with an inventory of major streams, ground cover and vegetation types, drainage patterns, major water bodies, reservoirs, fires and fire hazards.

Solar Activity Profiled

In mid-1971 there was an untimely change in the sun's overall magnetic field. This development caused an unusually rapid increase in the flow of cosmic rays in interplanetary space, according to Leonty Miroshnichenko of the USSR Academy of Sciences.

The level of the sun's activity is usually marked by the number of sunspots, and varies over a period of about 11 years. Similar patterns mark the flow of cosmic rays — high energy particles (mainly protons) reaching Earth from our galaxy. The relationship between the flow of cosmic rays and solar activity, however, is inverse. As the number of spots increases, the flow of particles decreases, and vice versa. The flow of solar plasma — the solar wind "blowing" in interplanetary space — carries with it "frozen" magnetic fields which expel cosmic particles from the solar system. When the wind slows down causing solar activity to fall, cosmic rays again fill interplanetary space, and their flow near Earth is intensified.

In recent years the attention of scientists has been directed toward the details in this variation: the energy spectrum of cosmic rays when solar activity is at its minimum and its maximum, and the shifting in the magnitude of the cosmic rays' flow with respect to the number of spots.

Soviet cosmophysicists (headed by Agasy Charakhchyan) were the first to notice sharp disruptions in the gradual temporal course of cosmic rays, caused by sharp changes in the number of sunspots. In January 1961, November 1963 and April 1964, the number of spots decreased very rapidly over a period of several days. Sharp declines in activity were followed by more gradual buildups in the intensity of the cosmic rays. Intensity rose to a maximum, while solar activity tended toward a minimum. These findings show that the irregularities of solar activity play an important, if not determining, role in the formation of electromagnetic conditions in the interplanetary medium.

During the 20th cycle of solar activity (1965-1969), the development of events was different when compared to the previous cycle. By the end of 1971, the flow of particles almost reached a maximum value, causing the earlier existing close relationship between solar activity and the cosmic rays to be suddenly upset around mid-1971.

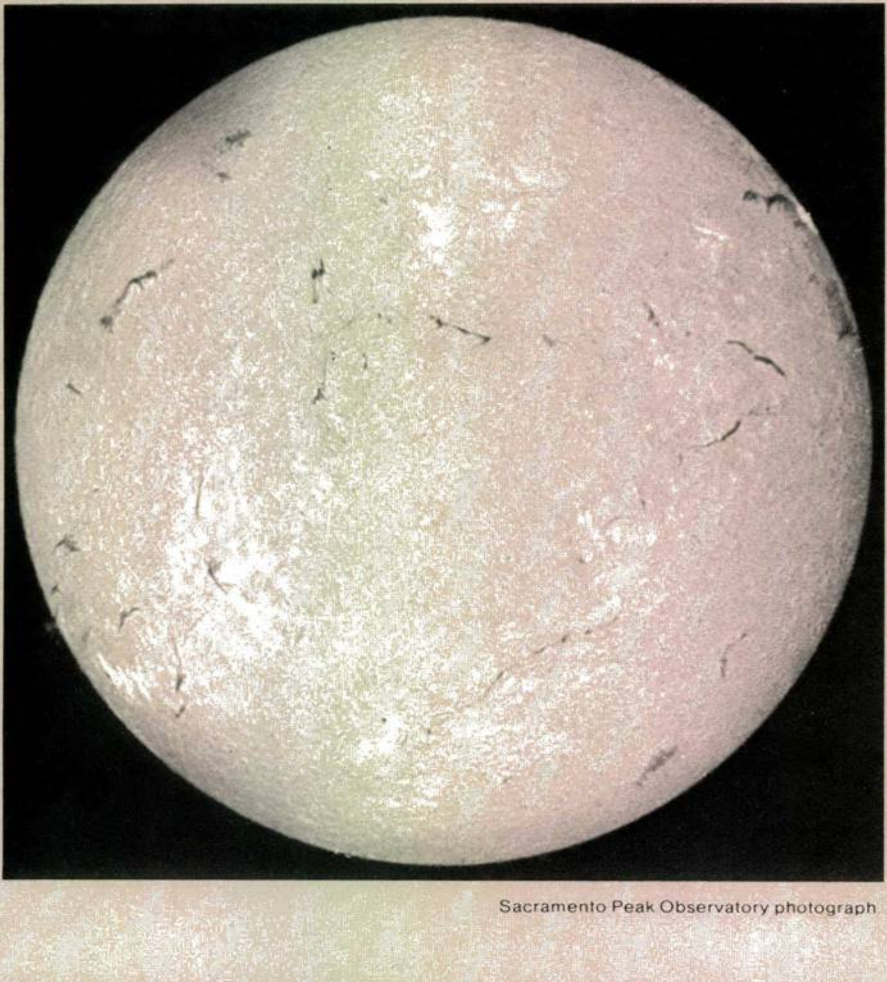
Measurements carried out by Lunokhod 1 confirmed that the typical course of the 11 year solar cycle was disturbed by the end of 1971. The fall in solar activity initially eased, but then began to grow (mainly in the sun's southern hemisphere), marking a second abnormal maximum in 1972.

Further measurements obtained by Soviet scientists on the lunar satellite Luna 19, and automatic interplanetary stations Mars 2 and 3 and Venera 8, showed that the flow of galactic particles in 1972 slowed sharply, while interplanetary space was literally "packed" with the flow of cosmic rays from solar flares — particularly in August 1972.

As yet it is difficult to say what caused the cosmic abnormalities of 1971-72. One thing is obvious: A new situation appeared in interplanetary and geophysical phenomena. During the last months of 1971, considerable variations in the velocity of Earth's diurnal rotation were observed.

Charakhchyan and his colleagues believe the prime cause of the anomalies in the cosmic rays is the change in the polarity of the sun's overall magnetic field. The northern and southern hemispheres change polarity signs every 11 years, so it takes a 22 year cycle to return to the sign of original polarity. If the previous 22 year cycle in the change of the sign had not been upset, the next one was to have taken place in 1965, and the one to follow was expected in 1976. At the point that the signs change, the overall magnetic field "disappears", favoring an increased influx of cosmic rays into the solar system.

These irregularities suggest that the changing of the poles probably took place in 1971 rather than in 1965. But why? The explanation might be as follows: The maximum of activity or number of spots of the 19th cycle was very high in 1957-58. Thus the magnetic flow emitted by the sun, characterizing the energy of the magnetic field, was quite powerful. Normally sunspot changes between "new" and "old" cycles proceed smoothly. Old spots "die", moving toward the sun's lower latitudes, while new ones arise at ±30 degrees latitude, advancing toward the equator and gradually gaining strength. To take up their places, the new spots must overcome the rem-



Sacramento Peak Observatory photograph

Sun *continued on page 70*

Solar Energy Applications

NASA and the Energy Research and Development Administration (ERDA) will spend $1.75 million this year in a joint program to use solar energy to provide heat and hot water for buildings at six space centers from Virginia to California.

The program should demonstrate that the relatively high initial cost of solar energy systems can be offset by substantial savings for electricity, oil and gas. Among the economically attractive applications are systems to supply all or part of the hot water or heat for a large office building, a manufacturing facility, cafeterias and laboratories at space centers in five states.

NASA will invest $500,000, and ERDA will spend $1.25 million for up to 10 separate projects at NASA facilities.

The projects, scheduled to be completed by the end of the fiscal year in October 1977, could reduce utility bills by as much as $250,000 annually.

The sun's energy will supply hot water for cafeterias at Dryden Flight Research Center (Edwards, Calif.) and Kennedy Space Center; hot water for photo labs at Ames Research Center, (Mountain View, Calif.) and Langley Research Center (Hampton, Va.), and heating and dehumidification for rooms housing sensitive computer and electronic equipment in the Mission Control Center at Johnson Space Center in Houston.

Engineers at Marshall Space Flight Center in Huntsville, Ala., have designed five solar projects. These will use the sun's energy to heat an office building; to heat liquid nitrogen to a gas for experiments and manufacturing at two Marshall facilities; to supply hot water for the cafeteria and restrooms in a 10 story office building, and to heat a warehouse used to store hydraulic equipment.

NASA is also providing its own funds for five smaller solar heating projects to be in operation at Ames, Kennedy and Marshall by the end of August.

NASA Requests Proposals For Large Space Structures

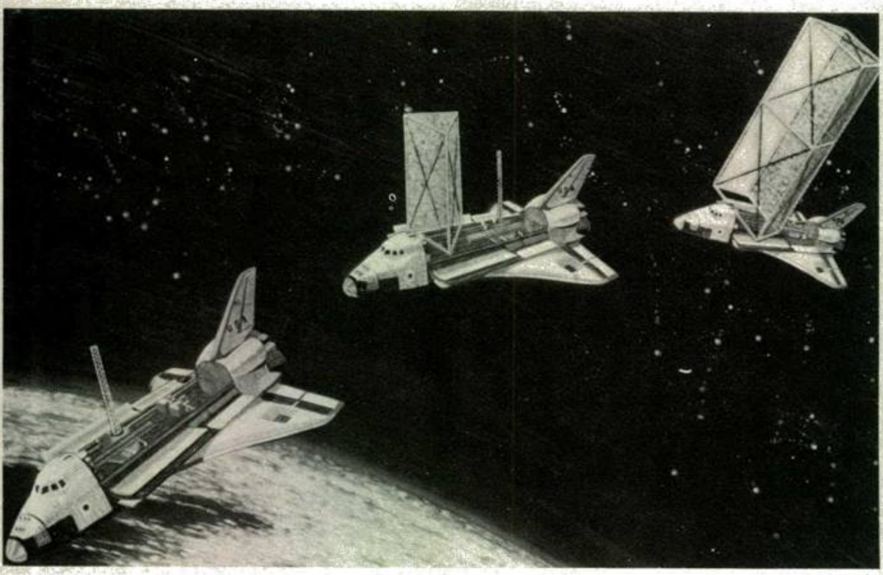
Future use of space to enhance life on Earth will involve a number of facilities and systems requiring large space structures. Such structures can lead to vastly improved methods of communications and improved monitoring of Earth resources, radio astronomy, public service and solar electrical power systems.

NASA's Marshall Space Flight Center has requested that industry submit study proposals that would provide data for NASA's use in developing techniques for packaging, transporting, fabricating, erecting and operating large structures in space. The study's goal is preparation for a major demonstration in space during 1983-84.

Demonstrations to be defined by the proposed study would begin on early Shuttle flights, with an automated beam fabrication module in the Shuttle bay to manufacture structural members. Material used in the first flight demonstration would be aluminum. In later flights and for the 1983-84 major demonstration, both aluminum and composite materials would be considered.

Only a few beams would be manufactured on early flights, followed by limited erection and assembly on later Shuttle flights. Finally, a large demonstration structure having a continuing use — such as a 100 kilowatt solar power facility — would be fabricated, erected and assembled in space. Such a facility could be used to supplement onboard Shuttle power for various experiments.

Capacity to manufacture and assemble large structures in space using the Shuttle would be used as a step toward development of a more complex fabrication and assembly facility as part of a space construction base in 1985 or beyond.



This illustration shows the three step development of a future assembly facility in space. The first step involves producing structural components by automated beam fabrication. The second step would involve additional beam fabrication and assembly. The last step combines the first two into a final assembled product such as a 100 kilowatt solar power facility. Missions will begin in the early 1980s, culminating in a Space Construction Base by the mid-1980s. NASA photograph.

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Sun *continued from page 69*

nants of the magnetic flow from the old cycle spots. If the magnetic flow of the old spots is too great, the new ones encounter substantial resistance in the process of their growth and movement to the equator. This is confirmed indirectly by two facts: the relatively low level of activity at the maximum of the 20th cycle (1969), and the unexpected second burst of activity in 1972.

The real picture of the processes in interplanetary space is indeed complex, and we do not yet know the mechanism whereby the "old" interplanetary field is replaced by the "new" one. If the above hypothesis is correct, then the anomaly of solar activity may have far reaching consequences both for the sun itself and for all of us. Magnetic storms, radio communication blackouts, droughts, floods and even man's health and creativity would be subject to the fiery breath and "caprices" of the sun. *Courtesy of Novosti Press Agency.*

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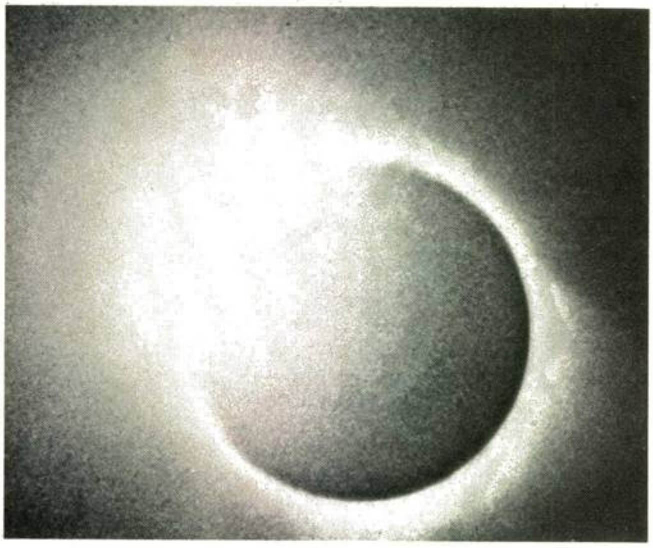

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STAR DOME

JUNE

by

James Mullaney and Henry J. Phillips

Three large adjoining constellations, each covering a sky area of more than 900 square degrees and each of which depicts a man, can be seen near their highest during warm June nights. The three — Bootes, Hercules and Ophiuchus — all contain distinct attractions for summer stargazers.

Bootes' proudest possession is the first magnitude star Arcturus. At magnitude -0.06, Arcturus is not only the brightest star in the constellation, but also in the sky's northern hemisphere; it is, in fact, the fourth brightest star in the entire sky! A simple method of unmistakably pinpointing the star is to continue the curve of the Big Dipper's handle southward until it hits Arcturus. Since Arcturus is the first star to appear through the evening twilight on June evenings, its rich orange color makes an attractive contrast with the deepening blue of the sky.

The stars of Bootes form the pattern of an elongated diamond, often referred to as a kite. Arcturus marks the base of this celestial plaything, while Bootes' other stars delinate the sail area. One of these stars, Epsilon Bootis, is named Izar. This name is from the Arabian word for girdle — referring not to the modern undergarment, but to the belt worn by the shepherd that the stars of Bootes represented to the Arabs; Izar marked the position of this belt. To the naked eye, it shines at magnitude 2.37, but the telescope reveals that Izar is actually a close binary. The brighter of the two stars is an orange giant of spectral class K1 (nearly identical with Arcturus), while the dimmer star has been called every color from blue to green to white — a striking example of how different observers see different things in the same object! The binary's beautiful color contrast led Wilhelm Struve to rechristen it Pulcherrima (Latin for "the most beautiful").

East of Izar lies another second magnitude star with two names. This is Alphecca or Gemma, the brightest gem in Corona Borealis, the northern crown. The derivation of the word "Gemma" is obvious; Alphecca is from the Arabian Al Na'ir al Fakkah, which means "the bright one of the dish". (Arabian astronomers pictured a dish or bowl here instead of a crown.) Alphecca is an eclipsing binary with a period of 17.4 days; it is a white main sequence star of spectral class A0, and its average magnitude is 2.23. As a variable, its magnitude range is only .11 magnitude, so naked eye observers aren't likely to notice much change.

The circlet of stars that marks Corona Borealis is wedged in between Bootes and an even larger constellation, Hercules. Hercules has no stars brighter than third magnitude, but it does contain four stars that form the keystone, the group's distinguishing feature.

Hercules is an oddity among constellation figures in that he stands on his head. The third magnitude star Ras Algethi marks Hercules' head; the keystone represents his trunk and his feet are near the head of Draco. In a previous Star Dome (August 1976), we expressed some curiosity over why Hercules should have this upside-down orientation. Prof. Guy Ottewell, in his **Astronomical Calendar 1977**, presents an answer that is most likely the solution to this puzzle. Because of precession (a wobbling motion of Earth on its axis), the sky's north pole was located in Draco, near the star Thuban, about 2500 B.C., when the ancient Near Easterners identified the constellations. At that time, Ras Algethi would have passed over the zenith, instead of well south of it as it does now. All that the people of the Near East would have had to do was face north, and Hercules would not have appeared upside-down at all. This explanation becomes doubly plausible when we consider that Ras Algethi is only a few degrees away from Rasalhague, the star that marks the head of Ophiuchus, the serpent holder. One giant therefore faced north as the other faced south, while their heads were directly above. (This also helps explain why Hercules, though dim, was so important to the ancients: It was circumpolar!)

Hercules, however, is a Greek hero; who did this constellation's stars represent to the Near Easterners, for whom it was so prominent? Evidence exists that the Sumerians — the earliest known civilization of the Near East — may have seen Gilgamesh, their greatest hero, in this star group.

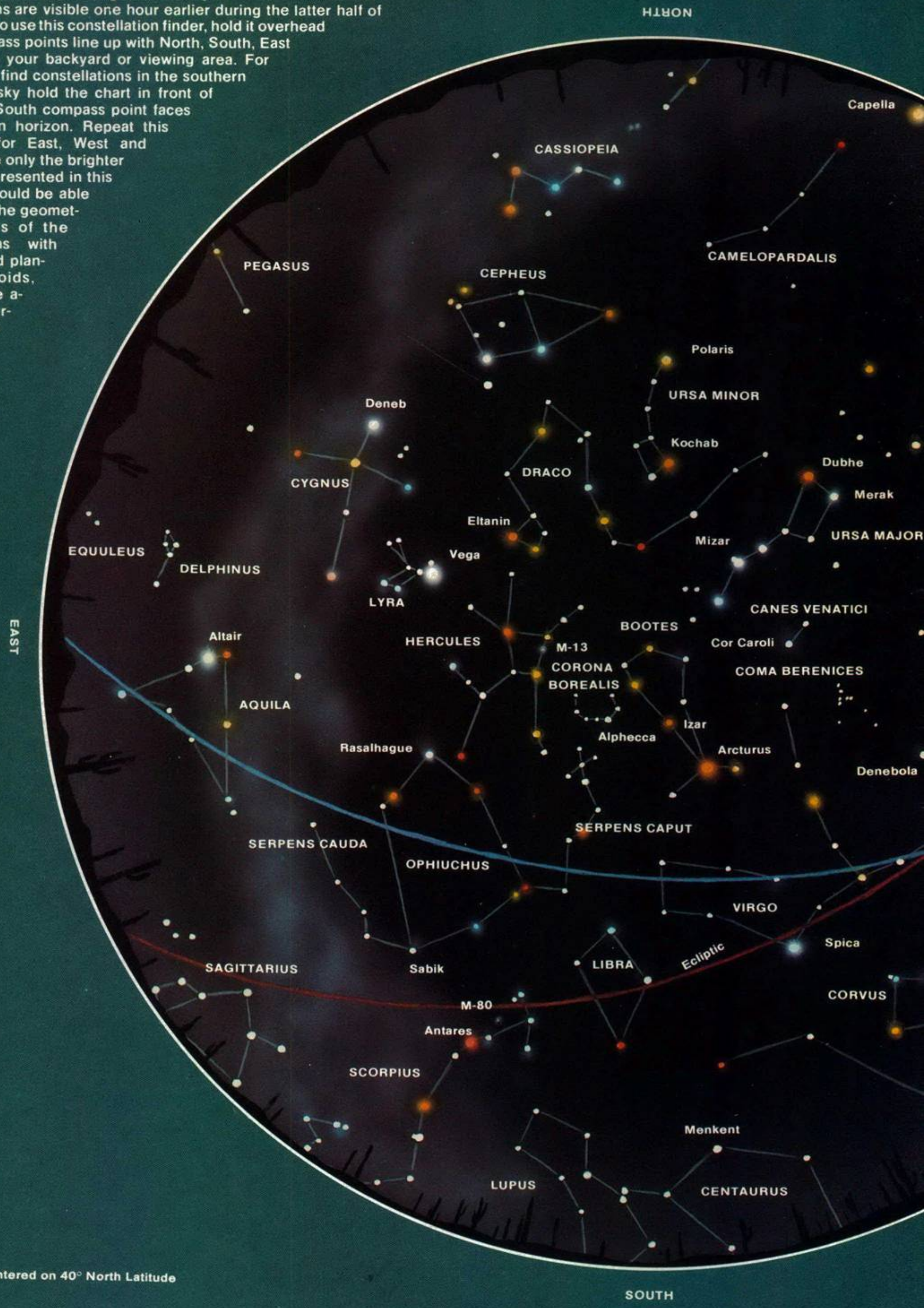
The Sumerian epic of Gilgamesh may well be the world's oldest surviving work of literature. Preserved on Assyrian cuneiform tablets, the epic was rediscovered as recently as the late 19th century. Painstaking translations have revealed the work's adventure and tragic power, which the following account can only roughly indicate.

Gilgamesh, king of Uruk, was superior to all other men in strength, wisdom and beauty. He could find no suitable friend to accompany him on his wars and heroic deeds until the gods created the "wild man" Enkidu. Enkidu lived with the animals in the forest until he was seduced by a harlot of Uruk and came with her to that city. After challening Gilgamesh to a wrestling match and being barely defeated by him, Enkidu became the king's long-sought companion. Together the two journeyed to the mysterious Cedar Forest, to destroy its evil guardian Humbaba.

Gilgamesh ignored Humbaba's plea for mercy and killed him, for which Humbaba's father Enlil, god of the winds, cursed him. Later, Ishtar, the Sumerian goddess of love, attempted to seduce Gilgamesh, but he rejected her. She set the wild Bull of Heaven on him, but Gilgamesh killed the Bull easily, and Enkidu threw the Bull's thigh in Ishtar's face. Mortally insulted, Ishtar demanded vengeance upon Gilgamesh from Anu, the king of the gods, and Enlil supported her. Anu punished Gilgamesh — not by killing him, but by sending illness and death to Enkidu. Enkidu's deathbed lament is one of the most moving sections of the epic.

The loss of his friend was more than

This Star Dome rendering approximates the sky as it appears at about 11:30 p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page **20**.


NORTH
Capella
CASSIOPEIA
CAMELOPARDALIS
PEGASUS
CEPHEUS
Polaris
URSA MINOR
Deneb
Kochab
Dubhe
DRACO
CYGNUS
Merak
Eltanin
Mizar
URSA MAJOR
EQUULEUS
DELPHINUS
Vega
LYRA
CANES VENATICI
EAST
Altair
HERCULES
BOOTES
M-13
Cor Caroli
CORONA BOREALIS
COMA BERENICES
AQUILA
Izar
Alphecca
Rasalhague
Arcturus
Denebola
SERPENS CAPUT
SERPENS CAUDA
OPHIUCHUS
VIRGO
Spica
SAGITTARIUS
Sabik
LIBRA
Ecliptic
CORVUS
M-80
Antares
SCORPIUS
Menkent
LUPUS
CENTAURUS
SOUTH

Map Centered on 40° North Latitude

AURIGA
GEMINI
Castor
Pollux
LYNX
M-44
CANCER
LEO MINOR
LEO
Regulus
Equator
SEXTANS
HYDRA
CRATER
WEST

Map by Adolf Schaller

Gilgamesh could bear, and with it came the realization that he too was doomed to die. He set out to find his ancestor Utnapishtim (the only mortal ever admitted to the company of the gods) and obtain from him the secret of immortality. After many adventures, including battles with lions and man-scorpions, Gilgamesh found Utnapishtim, who told how he saved himself from the great flood. His story is quite similar to the flood mentioned in the Book of Genesis — except that, instead of the awesome pact of the rainbow found there, the epic relates how the gods swarmed like flies over Utnapishtim's post-deluge sacrifice, bickering and arguing as they always did, with little thought for the worldwide destruction they had just wrought.

Utnapishtim intended to impress upon Gilgamesh the futility of his search, but could not. He therefore gave Gilgamesh instructions for obtaining a marvelous plant which, if eaten, would confer immortality. Gilgamesh, however, lost it to a serpent, who devoured it after it had been plucked. So Gilgamesh sadly returned to Uruk; the epic closes somberly with his death.

If the stars of Hercules originally represented Gilgamesh, those of Ophiuchus could easily have been the figure of Enkidu — especially since Ophiuchus is a "wild man" wrestling a serpent. The two "giants head-to-head" (to use the late Donald Menzel's phrase) may depict the Sumerians' most glorious heroes.

Close-Up

Ophiuchus Region

Ophiuchus is an extensive constellation that spreads high and wide in the summer sky and includes a magnificent portion of the Milky Way in its eastern and southern ramparts. The constellation's roughly pentagonal shape is well marked with fairly prominent stars, but its misty interior is obscure to the unaided eye. Webb called this figure "an extensive region, somewhat barren to the eye, but attractive to the telescope". Barns agreed, saying that Ophiuchus "is unsurpassed for sweeping-fields and sensations", and that it contains "a bewilderment of loose clusters, accentuated by encompassing black rayless space-deeps".

Large aperture binoculars and richest field telescopes are ideal for viewing the vast areas of dark obscuring nebulosity for which this month's region is noted. The multiple star Rho (ρ) Ophiuchi is near the edge of one such vacancy that extends southward as far as Antares in neighboring Scorpius. William Herschel remarked that this object is "on an intensely black ground, in a great blank space". He considered such areas to be actual holes in the Milky Way, so striking is their aspect in places. We know today that we aren't seeing holes, but rather the obscuring effect of dense clouds of dust and gas against the Milky Way background.

Another example of dark structures in the fabric of the heavens can be found 1-1/2 degrees northeast of Theta (θ) Ophiuchi. This unusual object is often referred to as the "S" or "elephant's trunk" nebula — and it looks very much like its namesakes. It is officially known as B-72, the 72nd entry in Barnard's roster of dark nebulae. Measuring some 20 minutes of arc in size, the S nebula fits nicely into a one degree eyepiece field and is well worth the search on a dark transparent night. When looking for such objects, however, remember that it is the *absence* of radiance, rather than its presence, that you'll be seeking!

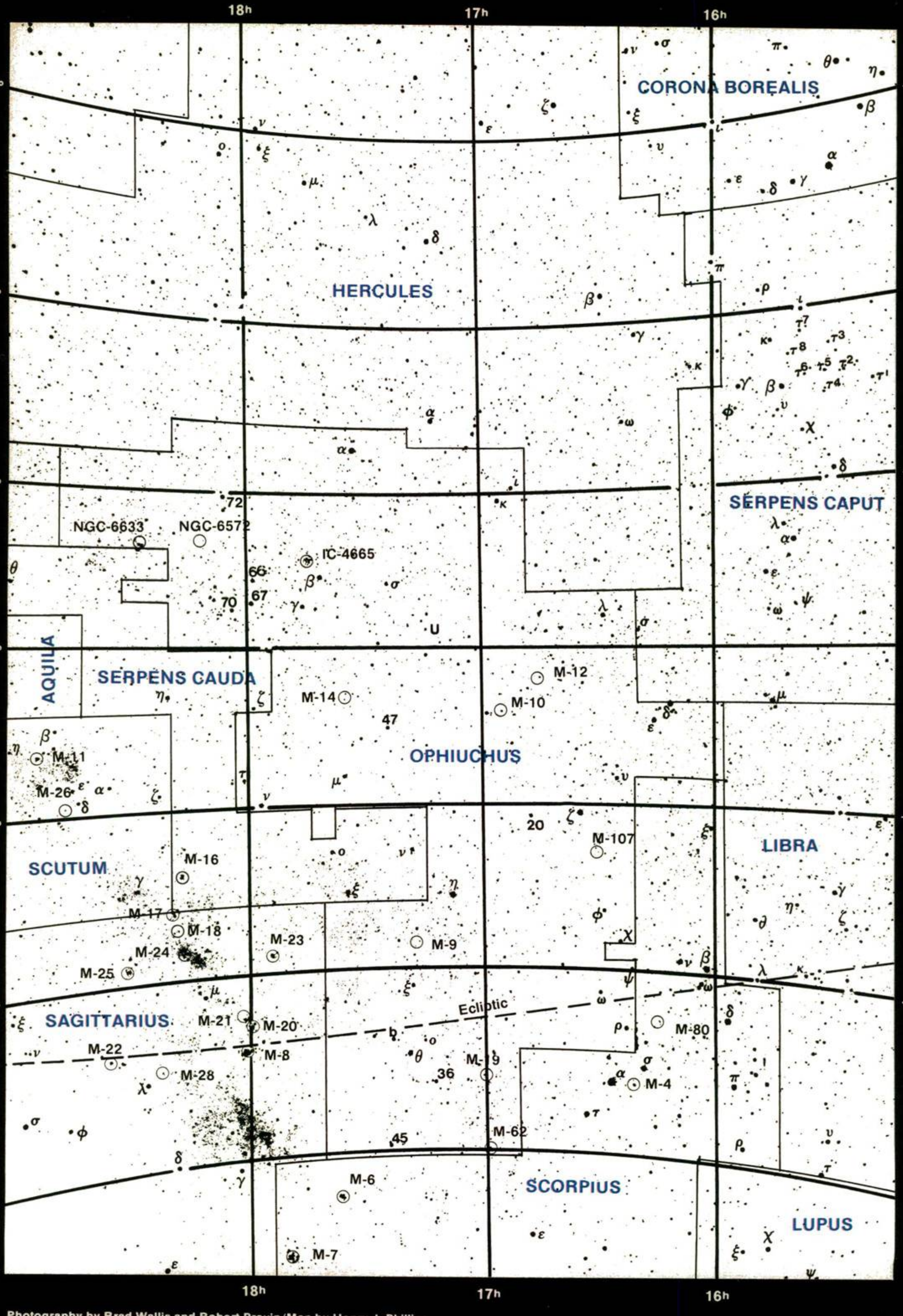
Yet another feature worth the attention of binocular users is the wide loose splash of stars known as IC-4665, about one degree northeast of Beta (β) Ophiuchi. Here some dozen or more stars are spread over 60 minutes of arc — an area twice the apparent size of our moon in the sky! The cluster glimmers near naked eye visibility at magnitude 5.4. Too large for most telescopic fields, IC-4665 is impressive in binoculars and finders.

M-10 and M-12

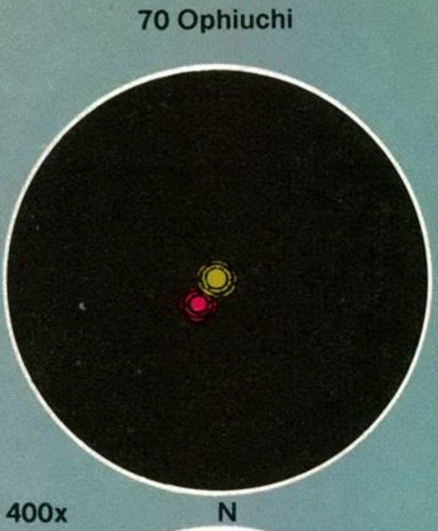
If last month's region (Draco) is the land of double stars, then Ophiuchus might well be dubbed the land of globular clusters, as a glance at our table should indicate. No less than seven such objects bright enough to rate an entry in Messier's list are to be found here, together with a number of lesser lights from the NGC catalog.

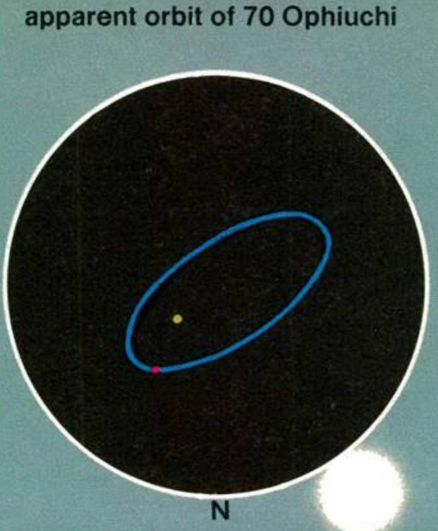
The best of these are the "twin" globulars, M-10 and M-12. Guide stars to them are few and far between, requiring some care in sweeping them up. M-10 can be found by scanning 10 degrees due east of Epsilon (ϵ), to a point just short of the star 30 Ophiuchi. Once there, move northwest in the sky toward Lambda (λ) Ophiuchi to pick up M-12. These two objects lie only three degrees apart, and on a good night, both are obvious in a finder.

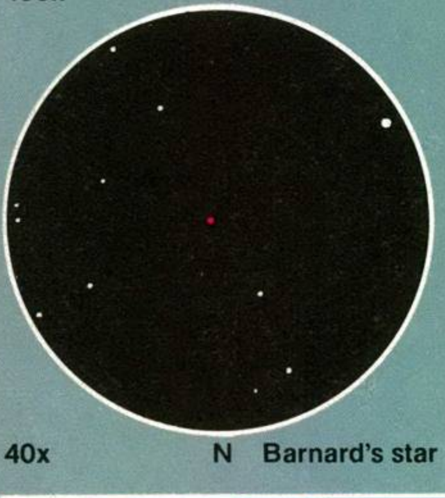
The catalog data for this duo suggest their similar appearance to visual observers: M-10 is magnitude 6.7 and eight minutes in size, while M-12 is 6.6 magnitude and nine minutes across. The stellar content of M-12 is perhaps somewhat more concentrated than that of M-10. A four inch telescope at 90 power will resolve the edges of both clusters — using averted vision in good seeing (image steadiness) —


18h
17h
16h
+30°
+20°
+10°
0°
-10°
-20°
-30°
CORONA BOREALIS
HERCULES
SERPENS CAPUT
AQUILA
SERPENS CAUDA
OPHIUCHUS
LIBRA
SCUTUM
SAGITTARIUS
SCORPIUS
LUPUS
Ecliptic
NGC-6633
NGC-6572
IC-4665
72
66
67
70
U
M-12
M-10
M-14
47
M-11
M-26
M-16
M-17
M-18
M-24
M-25
M-23
M-9
M-107
20
M-21
M-20
M-8
M-22
M-28
M-80
M-19
36
M-4
M-62
45
M-6
M-7

Photography by Brad Wallis and Robert Provin/Map by Henry J. Phillips







Above left: Perhaps the most immediately attractive double star in Ophiuchus is 70 Ophiuchi — a dramatically colored red and yellow pair, currently separated by about two seconds of arc. The drawing shows this binary as seen through a four inch refractor at 400 power; the field of view is about five minutes of arc. Above right: Over periods of several years, an observer can witness changes in position angle and separation in the 70 Ophiuchi system. This diagram shows the stars' orbit and current relative position; the companion moves clockwise. Left: The red star at the center of this field is the rapidly moving Barnard's star, seen through a six inch reflector at 40 power. The field of view is 70 minutes of arc. Drawings by James Mullaney.

Selected Objects — Ophiuchus Region

Object	Type	Mag	Size/Sep.	R.A. (1950) Dec.	
ρ(Rho)	★4	5.2,5.9, 6.6,7.1	4", 156", 152"	$16^{h}23^{m}$	—23°20'
M-107	GC	9.2	2'	$16^{h}30^{m}$	—12°57'
*M-12	GC	6.6	9'	$16^{h}45^{m}$	—01°52'
*M-10	GC	6.7	8'	$16^{h}55^{m}$	—04°02'
M-62	GC	6.6	4'	$16^{h}58^{m}$	—30°03'
M-19	GC	6.6	4'	$17^{h}00^{m}$	—26°11'
η(Eta)	★2	3.0,3.4	1"	$17^{h}08^{m}$	—15°41'
36 Ophiuchi	★2	5.3,5.3	4.6"	$17^{h}12^{m}$	—26°32'
o(Omicron)	★2	5.4,6.9	11"	$17^{h}15^{m}$	—24°14'
M-9	GC	7.3	2'	$17^{h}16^{m}$	—18°28'
*M-14	GC	7.7	3'	$17^{h}35^{m}$	—03°13'
IC-4665	OC	5.9	60'	$17^{h}44^{m}$	+05°44'
*Barnard's star	★F	9.5	—	$17^{h}55^{m}$	+04°24'
τ(Tau)	★2	5.3,6.0	2"	$18^{h}00^{m}$	—08°11'
*70 Ophiuchi	★2	4.3,6.0	2"	$18^{h}03^{m}$	+02°31'
*NGC-6572	PN	9.6	16"x13"	$18^{h}10^{m}$	+06°50'
NGC-6633	OC	4.9	20'	$18^{h}25^{m}$	+06°32'

*Detailed in Close-Up

★ 2,3,4 =Double or Multiple Star
★ F = Fast Moving Star
OC = Open Cluster
PH = Planetary Nebula
GC = Globular Cluster
Mag. = Magnitude
Sep. = Separation

and hints at resolution of their cores. An eight inch at 150 power breaks them into glittering stellar beehives, and the view becomes more exciting as aperture increases.

Webb called M-10 a "beautiful group" and noted that M-12 is "finely grouped". Barns described M-10 as "silvery massed . . . suns" and, like Webb, remarked on M-12's "distinguished surroundings". Lord Rosse noted the "tendency to curved branches" of M-10's stars and the "slightly spiral" arrangement of those in M-12. Both William and John Herschel easily resolved these clusters in their large, metal mirrored reflectors.

The features mentioned by the classic observers are still to be seen today, and there is always the possibility of adding something new to the visual impressions of these and other deep sky objects. Surely the twin globulars of Ophiuchus deserve your attention on clear warm summer nights, as they beckon from across more than 20,000 light-years of space.

M-14

In the same general swath of sky as M-10 and M-12 is another fine but neglected globular cluster that leads some observers to think of a trio here, rather than a duo. The third cluster is M-14, positioned five degrees north of Mu (μ) Ophiuchi.

At magnitude 7.7 and three minutes of arc in diameter, M-14 is both fainter and smaller than its neighbors, and (like most sky objects) has a "personality" all its own. This misty cloud seems much more tightly packed together than M-10 and M-12, presenting a resolution challenge to the observer. Barns called it "extended — like blown star-dust" in his 10 inch reflector. William Herschel saw it as large with glimpses of resolution in his favorite telescope — a "20 foot" reflector of 18.8 inches aperture; his son John described it as of "the finest star-dust".

M-14 does look larger in the telescope than its catalog size suggests; it is also rather difficult to break up into individual stars. In a six inch reflector at 100 power, this cluster is a splendid swarm of nebulous looking suns, while apertures of 12 inches and more invite inspection of its mysterious core.

NGC-6572

Globular clusters are by no means Ophiuchus' sole attraction. A case in point is the intensely glowing planetary nebula designated NGC-6572. It can be found by sweeping with the telescope a degree east and three degrees south of 72 Ophiuchi — itself the eastern corner of a triangle formed with Alpha (α) and Beta.

This unusual object is also known as Sigma 6. It was a discovery of the great observer Wilhelm Struve, made during his surveys of the sky for new double stars (of which he found more than 3,000!). It closely resembles NGC-6210 (Sigma 5) in Hercules (see Star Dome, August 1976).

The nebulosity of NGC-6572 is magnitude 9.6, and it has a 12th magnitude central star visible in larger instruments. NGC-6572 measures a slightly egg-shaped 16 by 13 seconds in size, although many observers feel that both it and NGC-6210 appear only half their catalog values in apparent angular extent. Despite this, NGC-6572 is well worth the time to locate. Even a three inch refractor at 45 power will distinguish the nebula from the surrounding stars to a trained eye, while a four inch telescope at 90 power shows its intensely glowing blue disk.

Webb provided us with the impressions of several observers including himself: "Small, very bright. Considered by Struve one of the most curious objects in the heavens. (John) Herschel, slightly hazy, D'Arrest, a little elliptical, five or six seconds (diameter), bluish green." Barns agreed with those observers: "A curious, bright gaseous unit, makes isoceles triangle with two eighth magnitude stars. Diameter six seconds. Bluish."

NGC-6572 shines with an eerie blue glow that has an intensity much greater than larger objects of its class. Indeed, some observers consider it the brightest object of its kind — at least per unit area. Like most planetaries, photographs spaced over many years reveal a slow outward expansion of its boundary from the dim nuclear star — an observation confirmed by the spectroscope. Various authorities place its distance from us at as much as 4,000 light-years.

Barnard's Star

Our attention shifts now from a planetary nebula to a possible planetary system! This is Barnard's famed "runaway" star, discovered in 1916. Its huge proper motion of more than 10 seconds of arc per year — the largest such motion known — carries this sun northward through the sky a distance equal to half our moon's apparent size in only 100 years.

At its distance of just under six light-years, Barnard's star is also our third nearest stellar neighbor, next to our sun and the Alpha Centauri system. It is a red dwarf star of spectral class M5, and shines faintly at magnitude 9.5.

In addition to its proximity and large proper motion, this object is unusual for yet another reason. It is perhaps the best known example of an *astrometric binary* — a star showing a wobble or perturbation in its path across the sky. Such antics indicate the presence of dull unseen companion bodies — either very small stars or very large planets — tugging on the visible star. After nearly a lifetime of intensive scrutiny of Barnard's star, astronomer Peter Van de Kamp is convinced that at least two large planets are orbiting this dwarf neighbor of ours — in short, another solar system!

Thus, despite its relative faintness, Barnard's star certainly merits thoughtful inspection during an exploration of the wonders of Ophiuchus. It lies within a degree of the star 66 Ophiuchi, itself just four degrees due east of Beta. As our drawing shows, if 66 is placed at the eastern edge of a low power telescopic field, Barnard's star will be found within the field of view. Even a three or four inch telescope makes its dim reddish-orange tint evident, in contrast with the surrounding stars.

70 Ophiuchi

This month's region contains many fine, colorful, easy double stars for general observation such as 36 and Omicron (o) Ophiuchi. It also holds a number of bright close binaries to delight the advanced observer — pairs such as Lambda, Tau (τ) and Eta (η) Ophiuchi. However, one object stands out clearly as the finest among all these. This is 70 Ophiuchi, easily found in a naked eye triangle of stars east of Gamma (γ) and Beta.

This superb duo consists of fourth and sixth magnitude suns, at present a tight two seconds of arc apart. Together they form one of the best examples of a binary system in the sky. The stars are bright and close to us, the orbit is large, and the period of revolution relatively short — just 88 years. More than two complete circuits have occurred since this pair was discovered by William Herschel in 1779. The motion is rapid enough to be quite evident from year to year even in a three inch telescope, making this system a favorite with double star observers.

Changes in position angle for 70 Ophiuchi are more noticeable than variations in separation. Our orbit diagram shows the present location of the elliptical orbit. The two stars were within 1.9 seconds of each other in 1975 and are presently opening slightly to a gap of 2.3 seconds, which they will reach in 1982. Thereafter, they will close again to a distance of 1.5 seconds in 1989, and then finally open gradually to a maximum of 6.8 seconds around 2024, at the "far end" of the orbit.

The position angle of the pair is presently about 345 degrees. Just seven years ago, however, they were at 55 degrees! Thus the companion star moved 70 degrees around its orbit in less than a decade — vivid proof of stellar dynamics in the depths of space.

At its distance of slightly less than 17 light-years, the apparent separations of 70 Ophiuchi correspond to actual spacial distances of the two suns of 12 astronomical units (AU) when closest, and 35 AUs when farthest apart. Since an AU is the Earth-sun distance, we can see that both members of this stellar duo would easily fit within the confines of our 100 AU diameter solar system.

Another point of interest concerning 70 Ophiuchi is that it is also an astrometric binary like Barnard's star. An unexplained orbital perturbation indicates the presence of a third body in the system, which makes this object either a triple star, or a double star with planets!

Could this unseen body have something to do with the following long-forgotten observation by John Herschel, as passed on to us by Webb: "Herschel observed that the (diffraction) rings around its telescopic image 'seem to have something peculiar. They are thin, and extend farther than in general;' on another occasion he remarks, in measuring it, 'Difficult, owing to the rings and appendages. I always find this star difficult from the above cause.' " Can some modern observer verify these curious experiences of Herschel?

Of more immediate interest to the visual observer — especially those who lack the patience to watch the orbital changes in 70 Ophiuchi over the years — is the lovely color of this pair. Most see the primary as deep yellow and the companion a rosy red, much as in our high power drawing, revealing the diffraction disks and rings.

Variations on these tints have been seen. Admiral Smyth, for example, gave them as "topaz and purplish", while Webb viewed them as yellow and purple at one time and as yellow and orange some years later. The great French observer Flammarion listed both stars as reddish; others have called them both golden yellow. The actual spectral type of the primary is K1 and that of the companion is K6; thus the impression that a definite contrast exists between these two suns is a real one.

Tinted pairs like 70 Ophiuchi make it easy to see why the stars have been called "flowers in the meadows of heaven". Indeed the noted lens maker John Brashear used different types of flowers to illustrate contrasting double star colors in some of his public talks! Thus, it seems nature has brought us full circle in our exalted study of the heavens. As Walt Whitman expressed it: "I believe a leaf of grass is no less than the journey-work of the stars."

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